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COMPREHENSIVE REPORT ON NASA ROCKET MOTOR DEFECTS INVESTIGATION

VOLUME II - TABLES AND FIGURES

Prepared under Contract No. NAS 1-6367
by
HERCULES INCORPORATED
Chemical Propulsion Division
Allegany Ballistics Laboratory
Cumberland, Maryland

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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COMPREHENSIVE REPORT

ON

NASA ROCKET MOTOR DEFECTS INVESTIGATION

FROM AUGUST 1966 TO JUNE 1968

by R. B. Enie and C. R. Hitt, Jr.

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VOLUME II

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TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X259			
NPP-502	Fwd Dome/Fiberglass Damage 2.4" lg x 0.10" x 1 ply deep 2.2" lg x 0.30" x 1 ply deep 4.0" lg x .05" x 1 ply deep 1.0" lg x .02" x 2 plies deep Metal parts damage and corrosion superficial Cylinder/Cork damage only Metal parts corrosion superficial Aft Dome/Metal parts superficial corrosion only Frayed fiberglass area	Satisfactory	Band of voids (pits) around entire circumference of center port 5" from forward adapter and 2½" wide.
NPP-525		Porosity in the forward propellant area to a maximum 3.5" depth x 20" lg from the forward adapter. Fiberglass Resin rich area approximately 7" lg from the forward skirt at 270°.	Band of voids at same location as NPP-502.
NPP-539		Propellant to embedment layer separation around the entire forward dome and hairline to 3/4" width by 3 3/4" to 10 1/4" depth	Band of voids at 6.25" aft of the forward adapter around the entire circumference of the center port. Separation between the propellant and forward embedment layer around the entire circumference and 0.58" width x 6.0" depth (See X-ray)

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
SV-212(Y-195)	Superficial metal parts damaged and corrosion.	Foreign material 1/8 to 3/16" long x 1/32 to 3/64" width located in the forward propellant at 270, 300, and 330°. Propellant to chamber bond separation around the entire forward dome 3 to 5" length x hairline to 1/8" width. Casting support to chamber separation around the entire circumference 1½" to 2½" length x hairline to 1/8" width.	
BSB-257	Superficial metal parts damage and corrosion.	Propellant to chamber separation around the entire forward dome 2 to 7" length x hairline to 1/16" width. Casting support to chamber separation around the entire circumference 1/4" to 1 1/2" length x hairline to 1/32" width. Propellant to chamber (insulator) at 240° in the aft dome 1 1/4" length x 1/8" to 3/16" width.	Propellant to insulator separation in the aft dome (see X-ray). Propellant solvent rich in the area of separation (adjacent to major fin slots).

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
BSB-261	Superficial metal parts damage and corrosion.	Propellant to chamber separation around the entire forward dome 1/4" to 1 7/8" length x hairline to 1/32" width. Casting support to chamber separation around the entire circumference 3/16" to complete separation x hairline to 1/32" width. Propellant to chamber (insulator) separation at 0^{o} and 120^{o} in the aft dome 3/16" to 5/8" length x hairline to 3/32" width.	
BSB-400	Superficial metal parts damage and corrosion.	Propellant to chamber bond separation over the entire forward dome 2 1/4" to 20" length x hairline to 1/16" width. Casting support to chamber separation over the entire circumference (complete separation length x hairline to 1/16" width).	

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
BSB-401	Superficial metal parts damage and corrosion.	Propellant to chamber bond separation over entire forward dome 3" to 7 13/16" length x hairline to 1/16". Casting support to chamber separation (completely) over the entire circumference.	
BSB-409	Superficial metal parts damage and corrosion.	Propellant to chamber bond separation over entire forward dome 1 5/8" to 2 5/8' length x hairline to 1/16" width. Casting support to chamber separation over the entire circumference 1" to 1 1/2" length x hairline to 1/32" width.	

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
BSB-424	Superficial metal parts damage and corrosion.	Propellant to chamber bond separation over the entire forward dome 1 5/8" to 4" length x hairline to 1/32" width. Casting support to chamber separation over the entire circumference 3/8" to 1 3/8" length x hairline to 1/32" width. Propellant to chamber (insulator) separation in the aft dome 1/8" to 2 1/16" length x hairline to 3/32" width over the entire circumference. Propellant to chamber (insulator) separation in the aft dome at 90° to 260° (See X-ray).	
BSB-242	Superficial metal parts damage	Propellant to chamber bond separation over the entire forward dome 5 1/4" to 7" length x 1/64" to 1/8" width. Casting support to chamber separation (complete).	

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
BSB-425	Superficial metal parts damage and corrosion.	Propellant to chamber bond separation over the entire forward dome 1 3/4" to 2 3/8" length x hairline to 1/16" width. Casting support to chamber separation over the entire circumference 3/4" to 1 1/2" length x hairline to 1/32" width. Propellant to chamber (insulator) separation in the aft dome 1/8" to 2" length x hairline to 1/32" width over the majority of the circumference.	Propellant to chamber (insulator) separation in the aft dome at 0° to 55° 1.50 maximum depth x .040 width (see X-ray).
BSB-445	Superficial metal parts damage and corrosion. Scuff mark 15" width x 2" length in the fiberglass in the cylindrical section 6" forward of the aft doubler. Scratch 0.3" length x 020" width x 002" depth in the fiberglass in the cylindrical section 2" forward of the aft doubler.	Propellant to chamber bond separation over the entire forward dome 5" to 15" length x 1/64" to 1/32" width. Casting support to chamber separation over the entire circumference 5/16" to 1 1/2" length x 1/64" to 1/16" width.	

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
BSB-446	Superficial metal parts damage and corrosion. Scratches in fiberglass around aft doubler stud holes #1, 3, 10, and 11 and delamination around hole #11. Discoloration in the fiberglass 1/2" wide x 2" long 6" forward of the aft doubler at 220°. Scuff mark on fiberglass in the cylindrical section 9" forward of the aft doubler at 0° to 45° and 270° to 0°.	Propellant to chamber bond separation over the entire forward dome 2 5/8" to 7 15/16" length x hairline to 3/32" width and in the cylindrical section at the forward edge of the insulator 3/16" length x 1/32" width at 120° and 240°. Casting support to chamber separation (complete) over the entire circumference hairline to 1/32" width.	
BSB-447	Superficial metal parts damage	Propellant to chamber bond separaover the entire forward dome 2 7/8" to 8" length x hairline to 1/16" width. Casting support to chamber separation at 180°, 210°, and 300°, 3/8" to 1 1/4" length x hairline to 1/32" width.	

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
BSB-453	Superficial metal parts damage.	Propellant to chamber bond separation over the entire forward dome 2 3/4" to 3 3/4" length x 1/64" to 1/8" width and in the cylindrical section 1/8" to 1 3/8" length x hairline to 1/32" width. Casting support to chamber separation (complete) over the entire circumference 1/32" to 1/16" width. Propellant voids in the aft dome and at the base of the slots at 0^{o}, 120^{o}, and 240^{o} 1/8" to 1 1/4" length x hairline to 3/32" width.	
BSB-454	Superficial metal parts damage and corrosion.	Propellant to chamber bond separation over majority of the forward dome 9/16" to 3 1/2" length x hairline to 1/32" width. Casting support to chamber separation over the entire circumference 1" to 1 5/16" length x 1/64" to 1/32" width.	
BSB-455	Superficial metal parts damage and corrosion.	Propellant to chamber bond separation over the entire forward dome 60^{o} 1/2" to 5 3/4" length x 1/64" to 1/32" width.	

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
NPP-414	Fwd Dome Light surface blemishes on adapter. V-shaped cut in fwd doubler approximately .250 lg x .250 x .150 dp. Cylindrical Section Balance weight missing at 0^{o}. Aft Dome Surface scratches around nozzle bolt holes. Corrosion on aft adapter.	Forward Core support to chamber separation. Major propellant to chamber separation. Cylindrical Extensive propellant-to-chamber and insulator-to-chamber separation. Aft Major propellant to insulator/cloth separation.	Foreign material present throughout interior. Sealing compound and solvent exudate around aft insulator area.
NPP-426	Fwd Dome Balance weight missing. Surface blemishes and scratches. Cylindrical Surface blemishes 'ft Dome Blemish and scuff marks on aft adapter.	Forward Core support to chamer separation. Major propellant-to-chamber separation Cylindrical Extensive propellant-to-chamber separation.	Foreign material present. Sealing compound and solvent exudate around aft insulator area. Solvent runs in propellant Potting compound and separation between aft propellant lip and insulator.

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
NPP-450	Fwd Dome Surface discoloration	Forward Core support to chamber separation. Extensive propellant-to-chamber separation.	Foreign material present. Solvent exudate present around aft insulator area. Propellant to aft insulator separation.
		Cylinarical Major propellant-to-chamber and insulator separation.	
	Aft Dome Superficial scratches. Corrosion on aft adapter.	Aft Major propellant to insulator/cloth separations. Voids in propellant.	
NPP-463	Fwd Dome Minor fiberglass damage. 1/8" hole in fwd doubler 1/4" deep. Edges of forward nubbin are rough.	Forward Core support to chamber separation. Major propellant-to-chamber bond separation.	Foreign material present. Sealing compound around aft propellant lip area.
	Cylindrical Fiberglass blemishes		

TABLE 1A - SUMMARY OF X248 AND X259 ROCKET MOTOR INSPECTION RESULTS (Continued)

MOTOR S/N	MOTOR VISUAL INSPECTION	RADIOGRAPHIC INSPECTION (Measurements as seen on film)	PROPELLANT VISUAL
X248			
NPP-475	Fwd Dome No studs present. Discoloration and surface scratches. Cut in forward doubler (.150 dp) Cylindrical Discoloration and surface scratches. Aft No studs present. Surface blemishes and discoloration.	Forward Core support to chamber separation. Major propellant-to-chamber bond separation. Cylindrical Major propellant-to-chamber bond separation. Aft Minor propellant-to-chamber bond separation.	Propellant to aft insulator separation. Foreign material present. Propellant lip .4" high in all major slots.

TABLE IB - SUMMARY OF EMPTY CHAMBER INSPECTION RESULTS

Chamber Type and Serial Number	Chamber Visual Inspection	Remarks
X248 S/N BS&B 246	Statically fired. Studs broken on both ends of chamber. Internal insulator has been removed. Chamber outside surface has fuzzed fiberglass condition (from outside storage). Fiberglass delaminated and bulged inside chamber over area approximately 10 in. long by 4 in. wide.	Not suitable for hydrotest vehicle
X248 S/N Y-182	Insulator pulled loose from chamber for 1 to 2 inches in length around complete I.D. next to cellulose acetate (CA) cloth. Insulator loose at aft end of chamber at 190° and 340°. Several minor scratches (½ in. to 6 in. long and 0.001 in. to 0.010 in. deep) on chamber O.D. Several studs missing on both ends of chamber.	Usable for hydrotest vehicle
X254 S/N Y-66	Fiberglass gouge on O.D. of cylindrical section near aft end between 0° and 90°. Some scuff marks on chamber O.D. Fuzzed fiberglass condition entire outside surface. Loose C.A. cloth inside of chamber.	Usable for hydrotest vehicle. Fiberglass defect must be evaluated for need of repair prior to hydrotesting.
X258 S/N RH-103	Loose strands of fiberglass on cylindrical section approximately 5 in. aft of fwd. ring face. Fwd. and aft insulators cracked at edge of adapters. NASA locking collar installed around aft adapter. Strain grids bonded to fwd. and aft domes. Lead indicators bonded to aft dome inside and outside.	Usable for hydrotest vehicle.
X258 S/N RH-104	Scratch on cylindrical section approximately 6 in. long. Scratch has been previously coated with resin. Epon 946 barrier coating entire inside surface. Good overall condition.	Usable for hydrotest vehicle.
X259 S/N NPP-98	Bruise (5/8 in. long by 1/2 in. wide) on chamber O.D. approximately 8 in. from fwd. skirt ring. Chamber is barrier coated inside. Good overall condition.	Usable for hydrotest vehicle.
X259 S/N NPP-118	Resin surface blemish (1 in. long by 1/2 in. wide) on cylindrical section approximately 7 in. from aft skirt ring. Aft insulator has 8 repaired areas. Good overall condition.	Usable for hydrotest vehicle.

TABLE 2

SUMMARY OF MOTOR DEFECTS AND FIRING RESULTS

X248 Motor S/N and Model	PROPELLANT/CASE DEFECTS: Defect Type and Location — Fwd Dome	Cyl. Sect.	Aft Dome	Defect Repaired — Fwd Dome	Cyl. Sect.	Aft Dome	Static Test Results — Fwd Dome	Cyl. Sect.	Aft Sect.	FIBERGLASS: Defect Type, Location, and Size	Defect Repair	Test Results
NPP-400, A5	CBS	CBS	None	No	No	N.A.	No Effect on Ballistics			None		
NPP-446, A6	CBS	None	None	No	N.A.	N.A.	"			None		
NPP-409, A5	CBS	None	None	No	N.A.	N.A.	"			Axial Gouges Cyl. Sect. 2.5" x 0.1" x 0.018" deep 2.5" x 0.1" x 0.027" deep	None None	0.027 in. deep defect peeled back and failed at 281 psia
NPP-447, A6	CBS	None	None	No	N.A.	N.A.				Transverse Gouges Aft Dome 1.0" x 0.1" x 0.052" deep 1.0" x 0.1" x 0.045" deep	None None	No Failure, 290 psia No Failure, 290 psia
NPP-401, A5	CBS	None	None	No	N.A.	N.A.				Axial Gouges Cyl. Sect. 2.5" x 0.1" x 0.015" deep 2.5" x 0.1" x 0.034" deep	None 3-Ply Repair	Motor failed at 0.049 seconds after first indication of pressure
NPP-455, A6	CBS	None	None	No	N.A.	N.A.				Transverse Gouges Fwd Dome 2.5" x 0.25" x 0.050" deep 2.5" x 0.25" x 0.040" deep	None None	No Failure No Failure
NPP-257, A5	CBS	None	Voids CBS	No	N.A.	Yes				Axial Gouges Cyl. Sect. 2.5" x 0.1" x 0.015" deep 2.5" x 0.1" x 0.034" deep	None 3-Ply Repair	No Failure, 380 psia, Delaminated No Failure, 380 psia
NPP-434, A6	CBS	None	Cracks Voids	No	N.A.	?				Transverse Gouge Fwd Dome 3.0" x 0.050" x 0.050" deep Two 0.375" Dia. Holes 100% deep	None 3-Ply Repairs	No Failure, 376 psia No Failure, 376 psia
NPP-261, A5	CBS	None	CBS	No	N.A.	Yes				Axial Gouges Cyl. Sect. 2.5" x 0.1" x 100% Deep 2.5" x 0.1" x 100% Deep	4-Ply Repair 4-Ply Repair	No Failure, 356 psia No Failure, 356 psia
NPP-242, A5	CBS	None	None	No	N.A.	N.A.				Axial Gouge Cyl, Sect. 7.5" x 0.1" x 100% Deep Two 0.375" Dia. Holes 100% deep "Natural" Gouge Fwd Dome 3.25" x 0.05" x 0.02" deep	4-Ply Repair 3-Ply Repair None	Motor Failed in Aft Dome at 390 psia No Failure, 390 psia No Failure, 390 psia No Failure, 390 psia
NPP-475, A6	CBS	Minor CBS	Minor CBS	No	No	Yes				Axial Gouge Cyl. Sect. 7.5" x 0.1" x 100% deep	3-Ply Repair	Failed, 340 psia, Sheared Bond Between patch and case
NPP-425, A6	CBS	CBS	CBS	No	No	Yes				Axial Gouge Cyl. Sect 15.0" x 0.1" x 100% deep	4-Ply Repair	Patch Failed on Shear at 351 ps Between Patch and Case

TABLE 2 (Continued)

SUMMARY OF MOTOR DEFECTS AND FIRING RESULTS

	PROPELLANT/CASE DEFECTS									FIBERGLASS		
	Defect Type and Location			Defect Repaired			Static Test Results			Defect Type, Location, and Size	Defect Repair	Test Results
X248 Motor S/N and Model	Fwd Dome	Cyl. Sect.	Aft Dome	Fwd Dome	Cyl. Sect.	Aft Dome	Fwd Dome	Cyl. Sect.	Aft Sect.			
NPP-445, A6	CBS	CBS	None	No	No	N.A.				Circumferential Gouges Cyl. Sect.		
										7.5" x 0.1" x 100% deep	4-Ply Repair	No Failure, 369 psia
										7.5" x 0.1" x 100% deep	3-Ply Repair	No Failure, 369 psia
NPP-453, A6	CBS	CBS	Minor Voids CBS	No	No	No				90°Angle Combination Axial and Circumferential Gouges, Cyl. Sect.		
										7.5" x 0.1" x 100% Deep Legs	4-Ply Repair	No Failure, 348 psia
										5.3" x 0.1" x 100% Deep Legs	4-Ply Repair	Patch Failed on Tension, 348 psia
Y-195, A10	CBS	None	None	No	No	No				Axial Area Type Defects Cyl. Sect.		
										2.5" x 0.4" x 100% deep	4-Ply Repair	No Failure, 385 psia
										2.5" x 0.8" x 100% deep	4-Ply Repair	No Failure, 385 psia
										7.5" x 0.4" x 100% deep	4-Ply Repair	No Failure, 385 psia
										7.5" x 0.2" x 100% deep	4-Ply Repair	Patch Failed in Tension at 385 psia
NPP-463, A6	CBS	None	None	No	N.A.	N.A.				Square Combination of Axial and Circumferential Gouges, Cyl. Sect.		
										7.5" x 0.1" x 100% deep All Four Sides	5-Ply Repair	No Failure, 388 psia
										5.3" x 0.1" x 100% deep All Four Sides	5-Ply Repair	No Failure, 388 psia

TABLE 3 - TENSILE STRENGTH S/81/901 GLASS CLOTH/EPON 946 PATCHES - 3 IN./MIN/IN.

Gage Length = 1.7 In. CHS = 5.0 in./min

Approximate Thickness of 1 Ply of Cloth = 0.014 in.

No. of Plies	Direction of Load	Specimen Number	Specimen Load (lb)	Stress (psi)	Deflection (in.)	Strain (in/in)	Modulus $x10^5$ (psi)
1	Warp	2	287	54,700	.136	.080	6.83
		3	312	59,400	.147	.087	6.86
		4	258	49,100	.132	.078	6.34
		5	303	57,700	.146	.086	6.72
1	Fill	1	255	48,600	.134	.079	6.17
		2	244	46,500	.128	.075	6.18
		3	228	43,400	.125	.074	5.92
		4	257	49,000	.142	.084	5.87
		5	243	46,300	.128	.075	6.16
2	Warp	1	552	52,600	.147	.087	6.07
		2	492	46,900	.138	.081	5.77
		3	502	47,800	.128	.075	6.35
		4	449	42,800	.139	.082	5.23
		5	570	54,300	.159	.094	5.81
3	Warp	1	830	52,700	.177	.104	5.07
		2	865	54,900	.182	.107	5.13
		3	900	57,100	.186	.109	5.22
		4	970	61,600	.189	.111	5.53
		5	830	52,700	.165	.097	5.43
4	Warp	1	1190	56,700	.191	.112	5.04
		2	1340	63,800	.195	.115	5.57
		3	1275	60,700	.193	.113	5.35
		4	1415	67,400	.215	.126	5.33
		5	1515	72,100	.232	.136	5.29

TABLE 4 - TENSILE STRENGTH S/81-901 GLASS CLOTH/EPON 946 PATCHES - 300 IN./MIN/IN.

Gage Length = 1.7 In. CHS = 495 in./min

Approximate Thickness of 1 Ply of Cloth = 0.014 in.

No. of Plies	Direction of Load	Specimen Number	Specimen Load (lb)	Stress (psi)	Deflection (in.)	Strain (in/in)	Modulus $x10^5$ (psi)
1	Warp	1	417	79,300	.143	.084	9.42
		2	385	73,400	.137	.081	9.10
		4	389	74,200	.137	.081	9.20
		5	385	73,400	.127	.075	9.82
2	Warp	2	812	74,600	.152	.090	8.33
		3	812	74,600	.154	.091	8.23
		4	750	69,000	.134	.079	8.75
		5	697	64,000	.134	.079	8.12
3	Warp	1	1176	74,800	.176	.104	7.22
		2	1217	77,300	.176	.104	7.47
		3	1140	72,500	.168	.099	7.33
		4	950	60,400	.146	.086	7.04
		5	1042	66,300	.148	.087	7.62
4	Warp	1	1500	71,400	.188	.111	6.45
		2	1518	72,300	.195	.115	6.29
		3	1690	80,500	.192	.113	7.12
		4	1615	77,000	.187	.110	7.00
		5	1540	73,300	.179	.105	6.96

TABLE 5 - EPON 946 SHEAR TEST - 3 IN./MIN/IN.

Specimen Number	Load (lb)	Shear Stress (psi)	Deflection (in.)	Strain (in./in.)	Shear Modulus (psi)
1	2090	1045	.086	.086	12,170
2	3160	1580	.120	.120	13,150
3	3425	1712.5	.148	.148	11,560
4	3700	1850	.150	.150	12,320
5	3950	1975	.162	.162	12,180
		Avg. 1632			

TABLE 6 - EPON 946 SHEAR TEST - 300 IN./MIN/IN.

Specimen Number	Load (lb)	Shear Stress (psi)	Deflection (in.)	Strain (in./in.)	Shear Modulus (psi)
6	3540	1770	.087	.087	20,200
7	2560	1280	.069	.069	18,600
8	3000	1500	.093	.093	16,100
9	3470	1735	.100	.100	17,350
10	3380	1690	.087	.087	19,400
		Avg. 1595			

TABLE 7 - HYDROBURST PRESSURES OF UNDEFECTED BOTTLES (GROUP I)

S/N	Helical Wt. (g)	% Resin Content by Weight	Burst Pressure (psig)
2*	170	15.3	(2700)
5	162	11.9	2300
8	163	13.1	2200
10	170	11.2	2225
15	168	15.0	2200
18	171	16.6	2100
		Avg.	2205

TABLE 8 - HYDROBURST PRESSURES OF DEFECTED BOTTLES (GROUP II, DEFECT DEPTH 50%)

S/N	Helical Wt. (g)	% Resin Content by Weight	Burst Pressure (psig)
9*	166	11.2	(1220)
14	167	14.9	1650
17	166	16.2	1740
20	170	14.7	1835
23	170	15.5	1730
24	164	14.3	1620
		Avg.	1715

*Burst pressures not included in averages.

TABLE 9 - HYDROBURST RESULTS FOR TWO-PLY REPAIR (GROUP III-1)
DEFECT DEPTH 50%

S/N	Helical Wt. (g)	% Resin Content by Weight	Location and Type of Failure	Burst Pressure (psig)
4	170	13.4	Entire Opposite Dome Burst	2040
11	175	10.7	At Patch in Shear	2415
16	168	14.8	Entire Patched Dome Burst	2135
			Avg.	2195

TABLE 10 - HYDROBURST RESULTS FOR THREE-PLY REPAIR (GROUP III-2)
DEFECT DEPTH 50%

S/N	Helical Wt. (g)	% Resin Content by Weight	Location and Type of Failure	Burst Pressure (psig)
3	190	14.5	Entire Opposite Dome Burst	2080
25*	193	12.8	Entire Opposite Dome Burst	3135
26*	179	14.1	Entire Patched Dome Burst	2685
			Avg.	2635

*Abnormally thick wall.

TABLE 11 - HYDROBURST RESULTS FOR TWO-PLY REPAIR OF 100% DEEP DEFECT

S/N	Helical Wt. (g)	% Resin Content by Weight	Location and Type of Failure	Burst Pressure (psig)
7	162	11.4	At Patch in Shear	1365
13	171	10.4	At Patch in Shear	1375
21	174	15.5	At Patch in Shear	1420
			Avg.	1385

TABLE 12 - HYDROBURST RESULTS FOR THREE-PLY REPAIR OF 100% DEEP DEFECT

S/N	Helical Wt. (g)	% Resin Content by Weight	Location and Type of Failure	Burst Pressure (psig)
6	185	11.7	At Patch in Shear	1905
19	173	12.6	At Patch in Shear	1790
23	162	15.7	At Patch in Tension	2205
			Avg.	1965

TABLE 13 - HOOP GAGE STRAIN COMPARISONS ON DEFECT NO. 1 X248 S/N NPP-463

Gage No.	Location	t = 7.46 sec. p = 300 psia	10.48 330	12.60 350	17.04 385	19.09 389	20.77 385	26.88 350	28.66 330	32.12 300
1	18.25" Aft 53°	1.02	1.11	1.18	1.31	1.34	1.34	1.25	1.19	1.09
2	13.75" Aft 58°	.45	.49	.53	.59	.60	.58	.52	.49	.43
3	15.25" Aft 58°	.65	.72	.79	.91	.93	.94	.88	.84	.77
4	16.75" Aft 58°	.63	.71	.76	.89	.95	.96	.90	.86	.79
5	18.25" Aft 58°	.98	1.07	1.12	1.28	1.35	1.38	1.32	1.26	1.17
6	19.75" Aft 58°	.65	.71	.78	.93	.98	1.00	.94	.90	.83
7	21.25" Aft 58°	.78	.86	.93	1.06	1.09	1.09	1.02	.97	.91
8	22.75" Aft 58°	.80	.87	.93	1.00	1.00	.99	.91	.87	.81
14	18.25" Aft 81½°	.49	.53	.57	.61	.60	.59	.53	.49	.45
19	18.25" Aft 100½°	.99	1.07	1.14	1.25	1.27	1.27	1.16	1.11	1.03
20	1.375" Aft 105½°	.31	.34	.37	.41	.41	.39	.33	.30	.25
21	15.25" Aft 105½°	.30	.36	.41	.50	.52	.52	.46	.43	.37
22	16.75" Aft 105½°	.36	.43	.49	.63	.69	.70	.64	.60	.53

TABLE 13 - HOOP GAGE STRAIN COMPARISONS ON DEFECT NO. 1 X248 S/N NPP-463 (Continued)

Gage No.	Location	t = 7.46 sec. ½ = 300 psia	10.48 330	12.60 350	17.04 385	19.09 389	20.77 385	26.88 350	28.66 330	32.12 300
23	18.25" Aft 105½°	.24	.29	.36	.51	.59	.60	.54	.51	.45
24	19.75" Aft 105½°	.38	.44	.51	.63	.67	.67	.62	.58	.51
25	21.25" Aft 105½°	.54	.57	.59	.61	.59	.58	.53	.49	.44
26	22.75" Aft 105½°	.47	.51	.54	.58	.57	.55	.49	.46	.41
27	18.25" Aft 110½°	1.11	1.21	1.28	1.42	1.45	1.45	1.39	1.34	1.27

TABLE 14 - HOOP AND AXIAL GAGE STRAIN COMPARISONS ON DEFECT NO. 2 X248 S/N NPP-463

Gage No.	Location & Type	t = 7.46 sec. p = 300 psia	10.48 330	12.60 350	17.04 385	19.09 389	20.77 385	26.88 350	28.66 330	32.12 300
28	19.35" Aft 233°, Hoop	.96	1.04	1.10	1.24	1.26	1.25	1.15	1.10	1.00
29	17.85" Aft 238°, Hoop	1.07	1.18	1.25	1.39	1.41	1.40	1.31	1.25	1.15
30	19.35" Aft 238°, Hoop	1.00	1.09	1.16	1.29	1.30	1.29	1.18	1.12	1.03
31	20.85" Aft 238°, Hoop	1.06	1.15	1.22	1.33	1.34	1.33	1.21	1.16	1.05
32	19.35" Aft 254½°, Hoop	.66	.72	.77	.84	.85	.85	.80	.76	.71
33	15.95" Aft 254½°, Axial	.34	.38	.40	.44	.44	.43	.39	.36	.33
34	16.75" Aft, 245°, Axial	.25	.29	.32	.37	.39	.39	.38	.36	.34
35	16.75" Aft 254½°, Axial	.21	.26	.29	.35	.37	.38	.34	.32	.29
36	16.75" Aft, 264°, Axial	.15	.20	.22	.28	.30	.31	.29	.27	.23
37	21.95" Aft, 245°, Axial	.20	.23	.25	.30	.32	.32	.29	.28	.25
38	21.95" Aft, 254½°, Axial	.17	.21	.24	.29	.30	.31	.27	.26	.23
39	21.95", Aft 264°, Axial	.13	.16	.19	.24	.25	.26	.24	22	.20
40	22.75" Aft, 254½°, Axial	.37	.41	.43	.46	.46	.46	.41	.38	.34

TABLE 14 - HOOP AND AXIAL GAGE STRAIN COMPARISONS ON DEFECT NO. 2 X248 S/N NPP-463 (Continued)

Gage No.	Location & Type	t - 7.46 sec. p = 300 psia	10.48 330	12.60 350	17.04 385	19.09 389	20.77 385	26.88 350	28.66 330	32.12 300
41	17.85" Aft, 271°, Hoop	.52	.58	.64	.73	.75	.75	.68	.65	.58
42	19.35" Aft, 271°, Hoop	.84	.92	.99	1.12	1.13	1.13	1.05	.99	.91
43	20.85" Aft 271°, Hoop	.93	1.03	1.11	1.25	1.27	1.28	1.18	1.12	1.04
44	19.35" Aft 276°, Hoop	.77	.85	.91	1.02	1.03	1.03	.96	.92	.86

TABLE 15- CONDITIONS ANALYZED IN COMPUTER PROGRAM

Condition	Defect width (in.) On Model	No. of Plies	Resin Thk. (in.)	Case Type
1	0.10	4	0.007	A5
2	0.20	4	0.007	A5
3	0.50	4	0.007	A5
4	0.10	3	0.007	A5
5	0.10	4	0.007	A6
6	0.10	4	0.0105	A5
7*	0.10	4	0.007	A5
8**	0.10	4	0.007	A6

* Plane Strain Constant of 0.79% added

** Void located between first and second ply of ply (0.50 in. long)

TABLE 16 - TENSILE-SHEAR VALUES FOR SPIRALLOY ADHESIVES (PSI)

	Epon 826/ Curing Agent D	Epon 946	Epirez/Epicure/ Cab-O-Sil
	(790) (1)	1060	1170
	990	990	1120
	970	1060	1110
Average	980	1037	1133

All tested at a strain rate of 0.05 in. per minute.

All specimens B-staged 16 hours at ambient conditions, cured at 200°F/ 2 hours.

(1) Faulty specimen. Not counted in average.

TABLE 17 - THREE-PLATE TENSILE SHEAR DATA
FOR S81-901 AND S81-904 GLASS CLOTHS

Cloth	Shear (psi)[a]	Range (psi)	Location of Failure
S81-901 (Refrigerated)	1832[c]	1825-1900	Spiralloy-resin interface
S81-904 (Non-refrigerated)[b]	1727[d]	1520-1937	Spiralloy-resin interface

a) Tested at a crosshead speed of 0.2 in. per minute at 77°F

b) Cloth aged 3 months after manufacture

c) Average of 5 specimens

d) Average of 3 specimens

TABLE 18 - BONDABILITY OF FRESH EPON 946 TO CURED EPON 946
(3-Plate Tensile-Shear Tests*)

Epon 946 Variables	Shear (psi)	Average (psi)
Cured + Fresh	685, 575, 575	612
Cured and Sanded + Fresh	825, 837, 823	828
B-staged + Fresh	550, 612, 550	571

*Tested at 0.2 in. per minute at 77°F.

TABLE 19 - BURST DATA FOR DEFECTED AND REPAIRED 6-INCH BOTTLES

Bottle No.	Description	Burst Pressure* (psi)	Type of Failure
78	Groove only	1350	Delamination at groove
79	Groove and patch	1580	Tensile break in patch
80	Control (no groove)	2300	Delamination in dome
81	Groove only	840	Delamination at groove
82	Groove and patch	1360	Tensile break in patch

TABLE 20 - BURST DATA FOR DEFECTED AND REPAIRED 3-INCH BOTTLES

	Bottle No.	Description	Burst Pressure* (psi)	Remarks
Group A	1-1	Control	4110	Burst
	1-2	Groove only	-	Leakage at pole piece
	1-3	Groove and patch	3900	Patch remained intact
	1-4	Groove only	540	Delamination at groove
Group B	1-5	Control	3690	Burst
	1-6	Groove and patch	1600	Weak spot in knuckle
	1-7	Groove and patch	3840	Patch intact
	1-8	Groove and patch	3150	Patch intact

*Test rate was 50 psi/second

TABLE 21 - STRAIN DATA AT PROGRESSIVE MAXIMUM PRESSURE X248 S/N NPP-400

Gage No.	Location*	Direction of Measured Strain	Strain at T1, P1 (%)	Strain at T2, P2 (%)	Strain at T3, P3 (%)
1	7 3/4" aft 0°	Hoop	0.50	0.55	0.95
7	7 3/4" aft 180°	Hoop	0.54	0.60	1.00
3	15 1/2" aft 0°	Hoop	0.62	0.64	0.91
9	15 1/2" aft 180°	Hoop	0.63	0.66	0.93
5	22 1/4" aft 0°	Hoop	0.98	0.96	1.06
11	22 1/4" aft 180°	Hoop	1.03	1.01	1.11
2	7 3/4" aft 0°	Axial	0.23	0.27	0.54
8	7 3/4" aft 180°	Axial	0.25	0.29	0.53
4	15 1/2" aft 0°	Axial	0.38	0.40	0.57
10	15 1/2" aft 180°	Axial	0.41	0.43	0.60
6	22 1/4" aft 0°	Axial	0.55	0.53	0.56
12	22 1/4" aft 180°	Axial	0.61	0.60	0.64

T_1 1.798 sec
P_1 275.6 psia

T_2 1.831 sec.
P_2 263.8 psia

T_3 22.956 sec.
P_3 255.1 psia

* Distance aft is measured from face of forward doubler.

TABLE 22 - STRAIN DATA FOR SAME PRESSURE AT DIFFERENT TIMES X248 S/N NPP-400

Gage No.	Location	Direction of Measured Strain	Strain at T1, P1 (%)	Strain at T2, P2 (%)	Strain at T3, P3 (%)	Strain at T4, P4 (%)
1	7 3/4" aft 0°	Hoop	0.72	0.82	0.85	0.90
7	7 3/4" aft 180°	Hoop	0.77	0.88	0.90	0.95
3	15 1/2" aft 0°	Hoop	0.71	0.77	0.82	0.85
9	15 1/2" aft 180°	Hoop	0.73	0.79	0.84	0.87
5	22 1/4" aft 0°	Hoop	0.87	0.89	0.98	0.98
11	22 1/4" aft 180°	Hoop	0.92	0.95	1.02	1.03
2	7 3/4" aft 0°	Axial	0.40	0.48	0.48	0.52
8	7 3/4 aft 180°	Axial	0.38	0.46	0.47	0.51
4	15 1/2" aft 0°	Axial	0.44	0.48	0.52	0.53
10	15 1/2" aft 180°	Axial	0.46	0.51	0.54	0.56
6	22 1/4" aft 0°	Axial	0.46	0.47	0.52	0.52
12	22 1/4" aft 180°	Axial	0.52	0.53	0.59	0.59

T_1 13.668
P_1 213.1

T_2 40.023
P_2 213.1

T_3 17.887
P_3 234.7

T_4 32.667
P_4 234.6

TABLE 23 - STRAIN DATA COMPARISON FOR IGNITION AND PROGRESSIVE MAXIMUM PRESSURE X248 S/N NPP-446

Gage No.	Location	Direction of Measured Strain	Strain at T1, P1 (%)	Strain at T2, P2 (%)
1	7 3/4" aft 0°	Hoop	0.48	0.64
7	7 3/4" aft 180°	Hoop	0.44	0.60
3	15 1/2" aft 0°	Hoop	0.52	0.61
9	15 1/2" aft 180°	Hoop	0.47	0.55
5	22 1/4" aft 0°	Hoop	0.64	0.64
11	22 1/4" aft 180°	Hoop	0.61	0.60
2	7 3/4" aft 0°	Axial	0.28	0.41
8	7 3/4" aft 180°	Axial	0.28	0.42
4	15 1/2" aft 0°	Axial	0.43	0.54
10	15 1/2" aft 180°	Axial	0.39	0.49
6	22 1/4" aft 0°	Axial	0.51	0.53
12	22 1/4" aft 180°	Axial	0.50	0.52

T_1 1.864 sec.
P_1 276.3 psi

T_2 25.473 sec.
P_2 251.43 psi

TABLE 24 - DEPTH GAGE MEASUREMENTS OF DEFECTS X248 S/N NPP-409

	1	2	3	4	5	
Fwd. End of Defect	.25	.50	.50	.50	.50	.25 Aft End of Defect

Defect #1	
Region	Depth (In.)
1	0.022
2	0.024
3	0.020
4	0.017
5	0.018
Length 2.52 In.	

Defect #2	
Region	Depth (In.)
1	0.026
2	0.030
3	0.032
4	0.031
5	0.026
Length 2.58 in.	

TABLE 25 - DEPTH GAGE MEASUREMENTS OF DEFECTS X248 S/N NPP-447

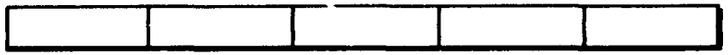
Defect #1	
Region	Depth (In.)
1	0.054
2	0.059
3	0.059
4	0.057

Length 1.0 In.

Defect #2	
Region	Depth (In.)
1	0.052
2	0.047
3	0.047
4	0.042

Length 1.0 In.

TABLE 26 - DEPTH GAGE MEASUREMENTS OF DEFECTS X248 S/N NPP-401



Defect #1	
Region	Depth (In.)
1	0.020
2	0.020
3	0.016
4	0.018
5	0.019

Length 2.50 In.

Defect #2	
Region	Depth (In.)
1	0.034
2	0.033
3	0.036
4	0.035
5	0.035

Length 2.50 In.

TABLE 27 - DEPTH GAGE MEASUREMENTS OF DEFECTS X248 S/N NPP-257

Defect #1	
Region	Depth (In.)
1	0.014
2	0.014
3	0.014
4	0.018
5	0.021

Length 2.50 In.

Defect #2	
Region	Depth (In.)
1	0.033
2	0.031
3	0.031
4	0.028
5	0.030

Length 2.50 In.

TABLE 28 - COMPARISONS OF STRAINS AT SIMILAR PRESSURES DIFFERENT TIMES X248 S/N NPP-454

Gage No.	t = 9.94 p = 305	11.54 330	15.01 350	21.52 376	27.60 350	28.19 330	32.96 305	Location and Type
16	.72	.79	.88	.97	.91	.83	.76	8.75" Aft, 0°, Hoop
17	.49	.54	.61	.70	.67	.63	.58	8.75" Aft, 0°, Axial
18	.64	.70	.79	.88	.83	.79	.69	8.75" Aft, 52½°, Hoop
19	.56	.62	.70	.79	.75	.71	.67	8.75" Aft, 52½°, Axial
20	.63	.71	.80	.89	.83	.78	.71	8.75" Aft, 90°, Hoop
21	.29	.38	.44	.53	.45	.40	.31	8.75" Aft, 90°, Axial
22	.89	.98	1.04	1.16	1.06	--	--	22.75" Aft, 0°, Hoop
23	.58	.63	.69	.76	.71	.67	.62	22.75" Aft, 0°, Axial
24	.99	1.06	1.12	1.22	1.21	1.18	1.12	22.75" Aft, 52½°, Hoop
25	.68	.70	.74	.82	.79	.76	.69	22.75" Aft, 52½°, Axial
26	.90	.97	1.05	1.14	1.07	1.00	.94	22.75" Aft, 90°, Hoop
27	.67	.72	.79	.86	.82	.77	.72	22.75" Aft, 90°, Axial

TABLE 29 - MODULUS OF ELASTICITY OF X248 MOTOR CASE AND FIBERGLASS CLOTH REPAIR MATERIALS

Materials	E_{RR}	E_{RC}	E_{RA}	E_{CC}	E_{CA}	E_{AA}	G_{RA}
E-glass 29°	1.05×10^{-6}	-1.50×10^{-8}	-1.64×10^{-7}	3.25×10^{-7}	-2.57×10^{-7}	9.94×10^{-7}	7.75×10^{-7}
E-glass 45°	1.04×10^{-6}	-6.24×10^{-8}	-6.24×10^{-8}	6.85×10^{-7}	-4.05×10^{-7}	6.85×10^{-7}	6.19×10^{-7}
E-glass 60°	1.05×10^{-6}	-1.59×10^{-7}	-1.54×10^{-8}	9.84×10^{-7}	-2.71×10^{-7}	3.41×10^{-7}	7.54×10^{-6}
E-glass 90°	8.87×10^{-7}	-1.89×10^{-7}	-2.80×10^{-8}	8.87×10^{-7}	-2.80×10^{-8}	1.55×10^{-7}	1.72×10^{-6}
S/81-901 Glass Cloth	8.52×10^{-6}	-2.72×10^{-7}	-2.72×10^{-7}	1.50×10^{-6}	-2.36×10^{-8}	1.65×10^{-6}	2.22×10^{-5}
Epon 946	3.04×10^{-5}	-1.03×10^{-5}	-1.03×10^{-5}	3.04×10^{-5}	-1.03×10^{-5}	3.04×10^{-5}	8.15×10^{-5}

$$E_{RR} = \frac{1}{E_R} \qquad E_{RC} = \frac{-\nu_{RC}}{E_R} \qquad E_{RA} = \frac{-\nu_{RA}}{E_R}$$

$$E_{CC} = \frac{1}{E_C} \qquad E_{CA} = \frac{-\nu_{CA}}{E_C} \qquad E_{AA} = \frac{1}{E_A}$$

$$G_{RA} = \frac{1}{G_{RA}}$$

C = circumferential

A = axial

R = radial

ν = Poisson's Ratio

TABLE 30 - COMPARISON OF BALLISTIC PERFORMANCE WITH THE MODEL SPECIFICATION

Characteristic	Dimension	Model Specification*				NPP-400	NPP-446
		Sigma (σ)	$\bar{X} + 2\sigma$	$\bar{X}$	$\bar{X} - 2\sigma$		
Total Impulse	lbf-sec	1023	88,649	86,603	84,557	86,105	85,350
Burning Time	sec	1.264	41.428	38.90	36.372	39.698	40.811
Average Thrust During Burning Time	lbf	94.7	2369.0	2179.6	1990.2	2122	2051
Average Pressure During Burning Time	psia	14.20	247.1	218.7	190.3	219	213

*ABL/X-82, "Model Specification, Motor Rocket, Solid Propellant, Model No. X248 A5 Scout (U)," dated May 1962.

TABLE 31 - COMPARATIVE BOND STRENGTHS OF X248 AND X259 COMPONENTS

Type of Bond	Ultimate Tensile Strength (psi)	Ultimate Shear Strength (psi)
BUU - BUU	115	
CYI - CYI[1]	145	
CYI - E/E (10:7)	77[2]	
CYI - Epon 946	81[2]	
Epon 946 - Fiberglass[3]		1630[4]
		1595[5]
E/E - Fiberglass		1133[6]
Cured Fiberglass[3] - Uncured Resin[7]		980[6]
Epon 946 SBR[8]	380	150[9]

(1) JANAF type II dogbones 1/4" thick, die-cut. Tested at 0.74 in/in/min.

(2) Crosshead speed 0.2 in/min at 77F.

(3) Mat of ECG-140-801 glass roving; matrix resin Epon 826/Shell Curing Agent D. Surfaces sanded before bonding with Epon 946.

(4) Double lap shear specimens. Crosshead speed 3" in/min at 77F.

(5) Double lap shear specimens. Crosshead speed 300 in/min at 77F.

(6) Single lap shear specimens. Crosshead speed 0.05 in/min at 77F.

(7) Epon 826/Shell Curing Agent D.

(8) Asbestos filled SBR, buffed and cleaned with methylene chloride.

(9) Single lap shear specimens - ASTM D-1002.

TABLE 32 - SOME PROPERTIES OF AMBIENT CURE RESIN SYSTEMS

System	Max. Exotherm[1] (°F)	Uncured Viscosity (cps)	Taliani Stability		Tensile Strength at 77F[2] (psi)	Elongation at 77F (%)
			Uncured	Cured		
Epon 953	-	2000	passed	passed	2000	-
Epon 946[3]	-	3800	passed	passed	2100	62
Epons 871/815/946B[4]	124	1400	passed	passed	-	-
Epirez 504/Epicure 855/3% Bentone	-	-	not passed	passed	2400	49
Multron R-18/TD-80/24% DMS[5]	118	1400				
Multron %-18/TD-80/25% DBE[6]		1850				

(1) For a 4.5 lb casting, 6" dia. x 3.5" long

(2) Crosshead speed 0.2 in/min

(3) Epon 953 + 3% Bentone-27

(4) Sprint potting compound

(5) Polaris A3 Potting Compound. DMS = dimethyl sebacate

(6) DBE = dibenzyl ether, a replacement for DMS

TABLE 33 - SOME PROPERTIES OF AMBIENT CURE RESIN SYSTEMS

Ambient Storage Time	Tensile Strength (psi)	Tensile Mod. (psi)	Elong. (%)	Remarks
0	320	610	77	JANAF type II dogbones
1 month	310	500	66	Cured at 120F/3 days
2 months	330	570	72	Tested at 2 in./min.
3 months	300	690	67	at 77F
0	250	478	46	Dogbones cured at 300F/3 hrs. after 16 hr. ambient B-stage

Time (hrs)	Viscosity cps	Remarks
0	1250	Brookfield Spindle TA, 4 RPM, 75F
1	1400	
2	2200	
2.75	5300	Gelation[1] Exotherm to 124F

Compatibility with Casting Solvent (C. S.)[2]

Specimen	Pressure (mm Hg)	Time (hr)	Remarks
Cured 20 mil film + CS	29	23	Modified Taliani test
Uncured resin mix + CS	170	23	HD-CP-3900
Cured 20 mil film soak in CS			13.7% weight gain in 7 days at 77F, 9.12% NG absorbance

[1] A 4.5 lb. batch of resin gelled in 230 min (3.8 hrs) and reached a max. exotherm of 150F.

[2] NG/TA/NDPA (75/24/1)

All data from P. H. Skidmore, "Specitic Problem Report, ABL #298," Aug. 10, 1965.

TABLE 34 - MODIFICATION OF SPRINT POTTING COMPOUND

		Formulation				Type II Dogbone Data Tested at 0.2 in./in./min at 77°F							
						Tensile Strength (psi)		Tensile Modulus (psi)		Elongation (%)		Viscosity (cp	
Set	Batch	Epon 871	Epon 815	Epon 946B	Stoichiometric	77°F	300°F	77°F	300°F	77°F	300°F	Initial	Final / urs
2	A	90	10	13.0	Yes	1050(1)	-	-	-	>67	-	1250(5)	2000/2
4	B	70	30	15.8	Yes	1585(2)	2040	16,490	38,600	36	28	720(6)	5000/3
4	C	50	50	18.6	Yes	5768(2)	6100	122,150	250,500	8	4	630(6)	2950/2
2	B	70	30	11.5	No	403(3)	2030	1,356	26,400	48	46	1000(5)	1750/2
3	C	50	50	10.0	No	194(2)	1800	896	7,300	63	18	750(7)	1000/2 3500/3
2	C	50	50	10.0	No	166(3)	1230	508	3,200	76	29	875(5)	1500/2
1	C	50	50	10.0	No	608(4)	-	4,450	-	44	-	-	-

(1) Ambient cure of Sprint slivers for 3 days tested at 0.1 in./in./min at 77°F.

(2) Ambient cure for 25 days before testing.

(3) Ambient cure for 30 days before testing; samples cured at 300°F for 3 hr were B-staged 16 hr at ambient.

(4) Ambient cure for 47 days.

(5) Brookfield Spindle TA, 4 RPM, 77 ± 5°F.

(6) Brookfield Spindle #1, 6 RPM, 77 ± 5°F.

(7) Brookfield Spindle #3, 4 RPM, 77 ± 5°F.

TABLE 35

TABLE 35 - TENSILE BOND STRENGTHS BETWEEN POTTING COMPOUNDS 2A, 2B and X248 MOTOR COMPONENTS

Component	Average Tensile Strength (psi) 2A	2B	Location of Failure 2A	2B
BUU	130(1)	-	2A to BUU	-
NBR	403(1)	458(4)	2A to metal(3)	Half 2B to NBR, half 2B to metal
Spiralloy	467(1)	615(4)	2A to Spiralloy	Spiralloy delaminated
Cured Armstrong A2/W	623(2)	2663(5)	67% A2 to metal	67% A2 to 2A
			33% A2 to 2A	33% A2 to itself
Aged Case Bond Interface	69(3)		2A to case bond	-

All specimens cured 3 days at 120°F, and tested at crosshead speed of 0.2 in./min at 77°F

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(1) These samples utilized the ABL 2 in. x 2 in. steel tensile bond test plates. The sandblasted steel plates were coated with formula 2A adhesive and B-staged (ambient temperature for 16 hours). Freshly mixed Formula 2A was then applied to both sides of the material being tested, BUU (machined surface), NBR (buffed) or Spiralloy mat (not sanded). The steel plates were then bonded to the sample materials, with the B-staged Formula 2A adhesive being tested. Figure 143 shows the cross-section of these samples.

(2) These samples utilized the ABL 2 in. x 2 in. steel tensile bond test plates. Both plates of each sample were coated with Armstrong A2/Activator W and cured. The cured Armstrong A2 adhesive surface was then coated with Formula 2A, and the two plates were bonded together. Figure 144 shows the cross-section of these samples.

(3) These samples utilized the ABL 2 in. x 2 in. steel tensile bond test plates. The motor samples were bonded to the test plates with Armstrong A2/Activator W. The motor samples were 2 in square x 1 in. thick and were taken from fired NPP-242. The samples comprised insulation (NBR), Armstrong A2 adhesive, CA cloth, case bond, and propellant. The CA cloth and case bond interface was manually separated and rebonded with Formula 2A, without surface preparation. See Figure 145 for the cross section of these samples.

(4) These samples were the same as (1) except that Formula 2B adhesive and round ASTM tensile plates were used.

(5) These samples were the same as (2) except that Formula 2B adhesive and round ASTM tensile plates were used.

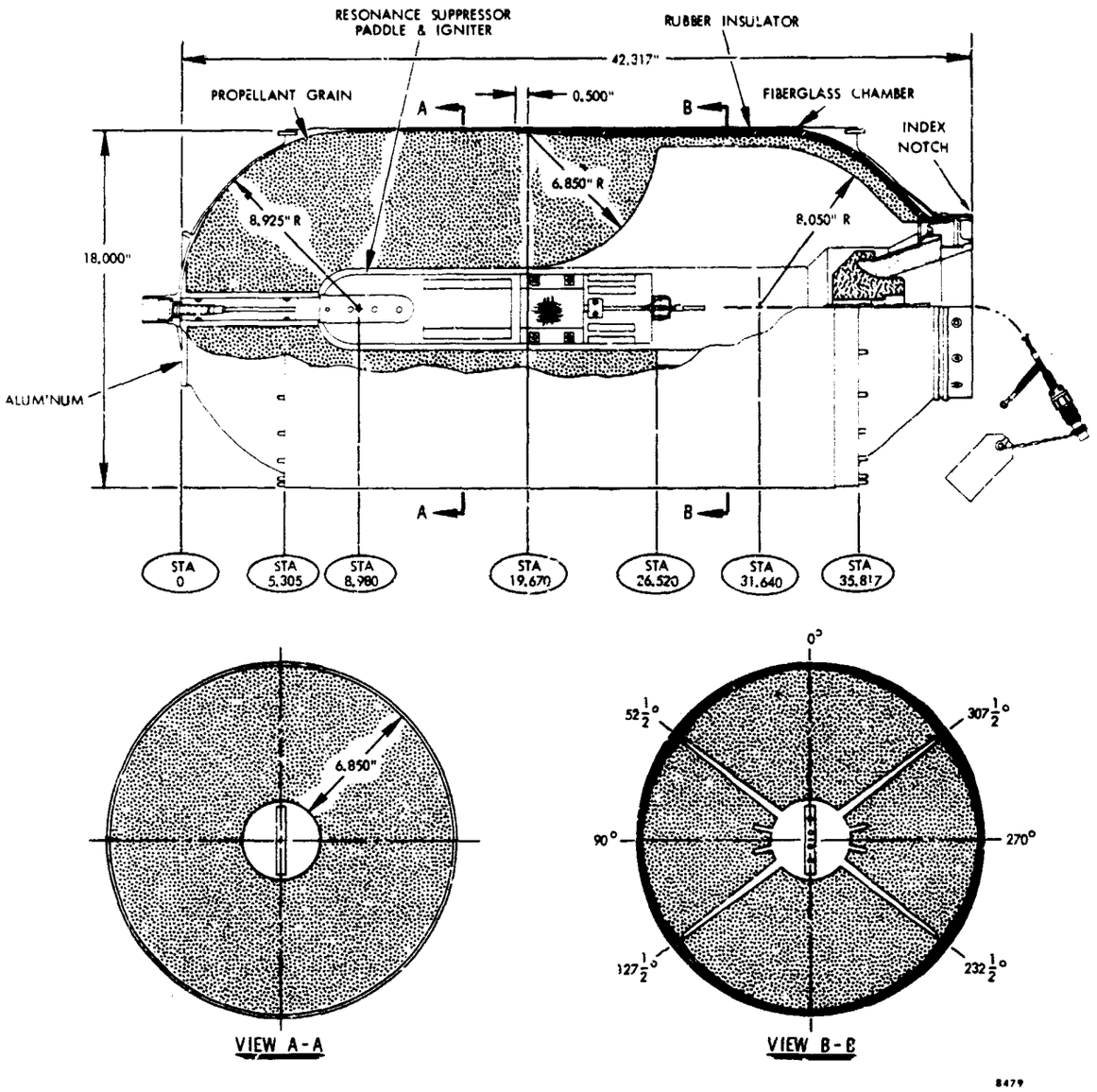


FIGURE 1 ROCKET MOTOR X248 W/SEA LEVEL NOZZLE

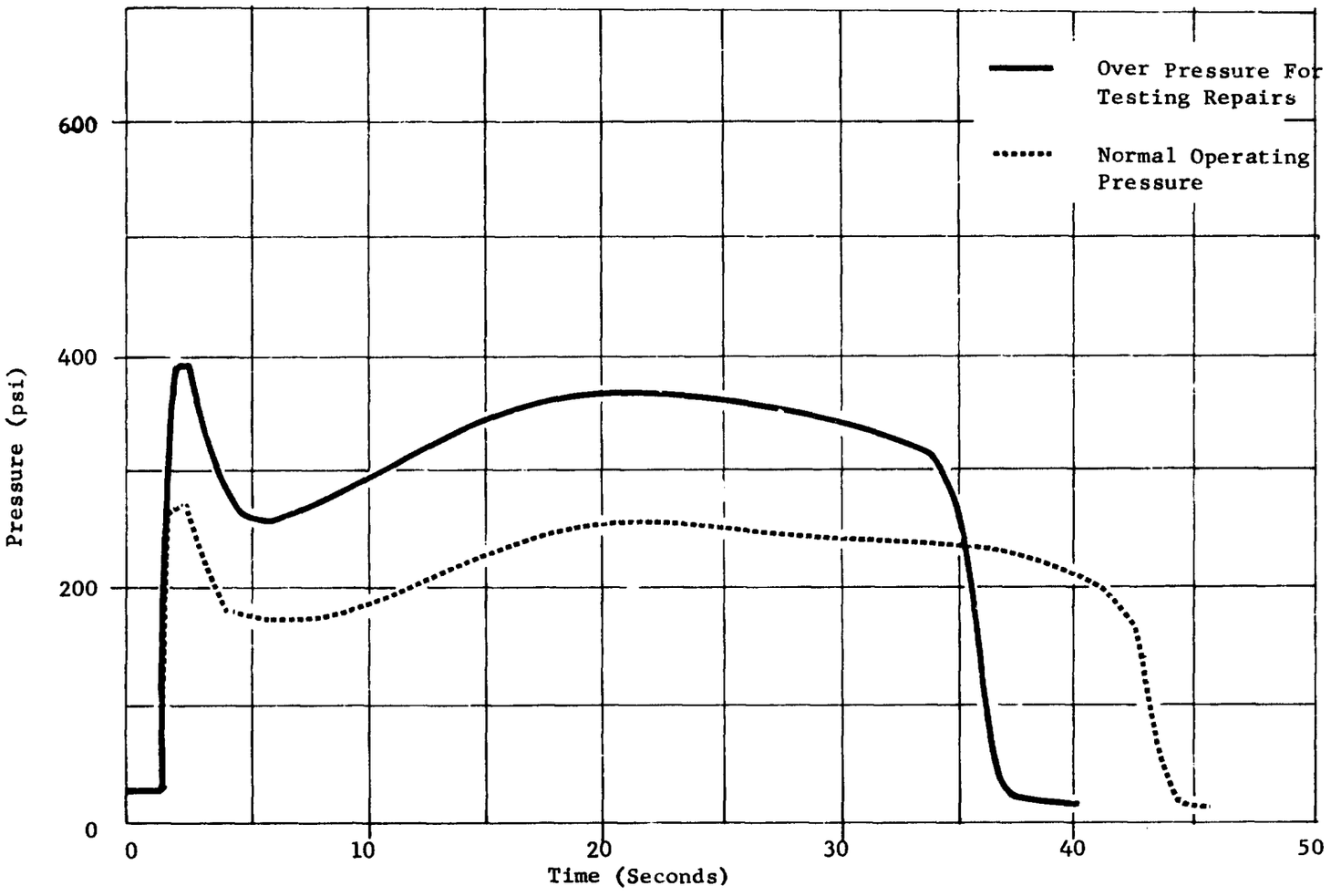


FIGURE 2 - TYPICAL PRESSURE-TIME TRACES FOR ROCKET MOTOR X248

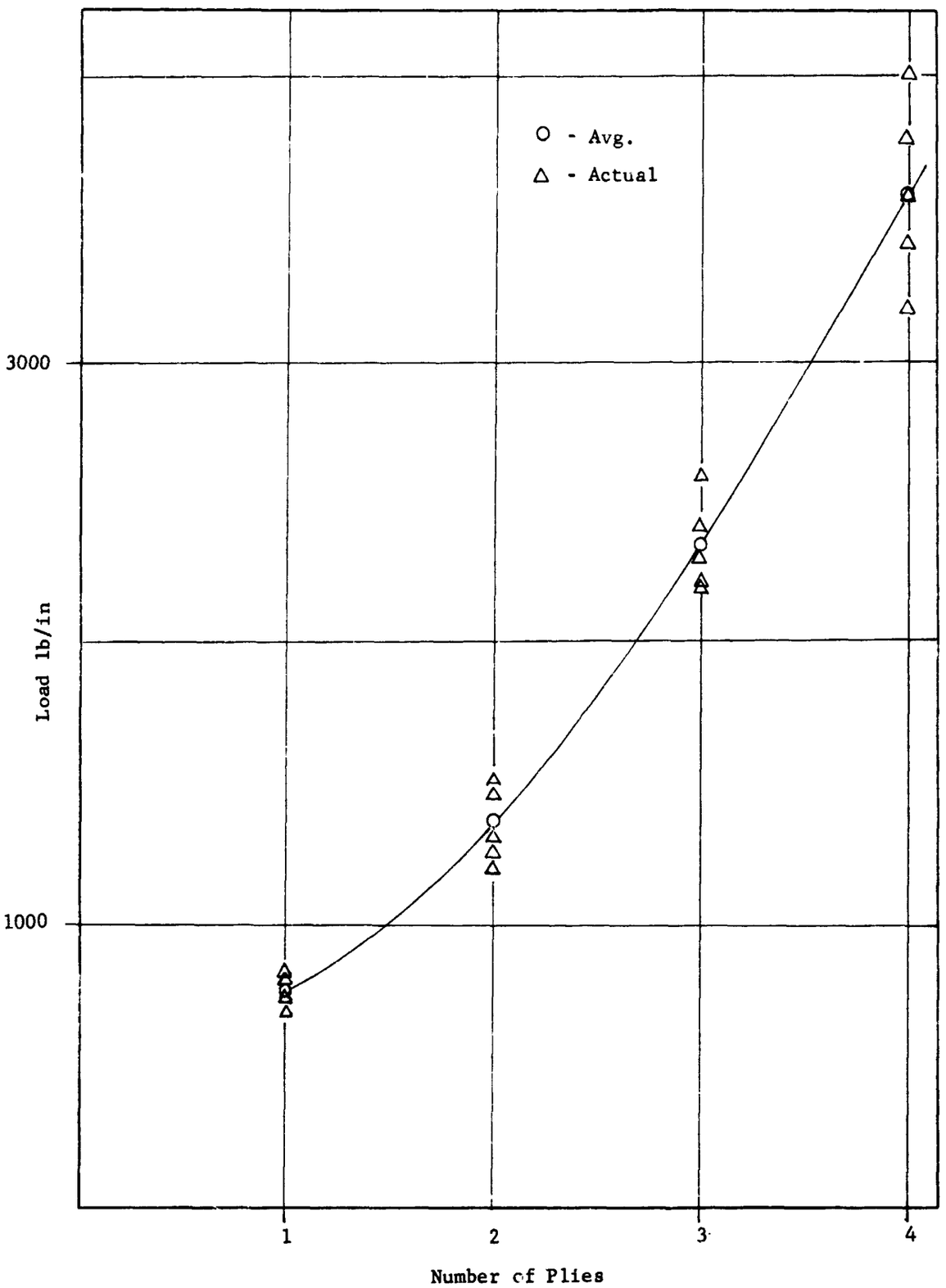
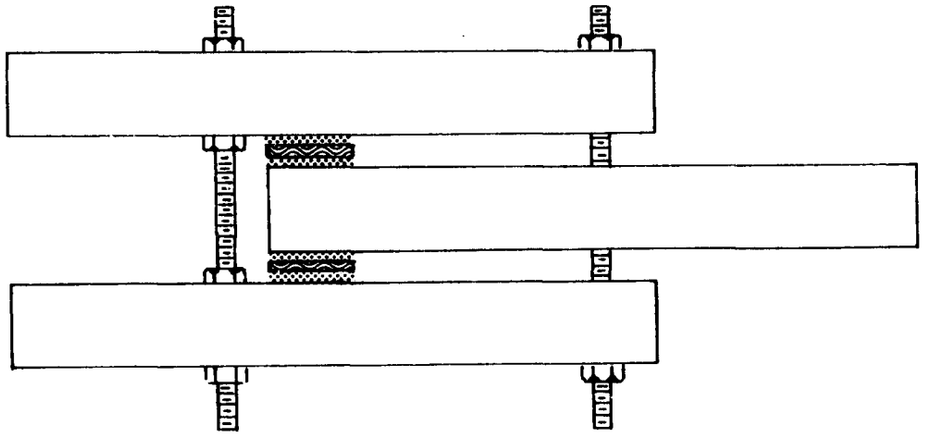


FIGURE 3 - PATCH LOAD CARRYING CAPABILITY
AT 3 IN./MIN/IN.



Epon 946

X248 Fiberglass

FIGURE 4 - DOUBLE-LAP SHEAR SPECIMENS

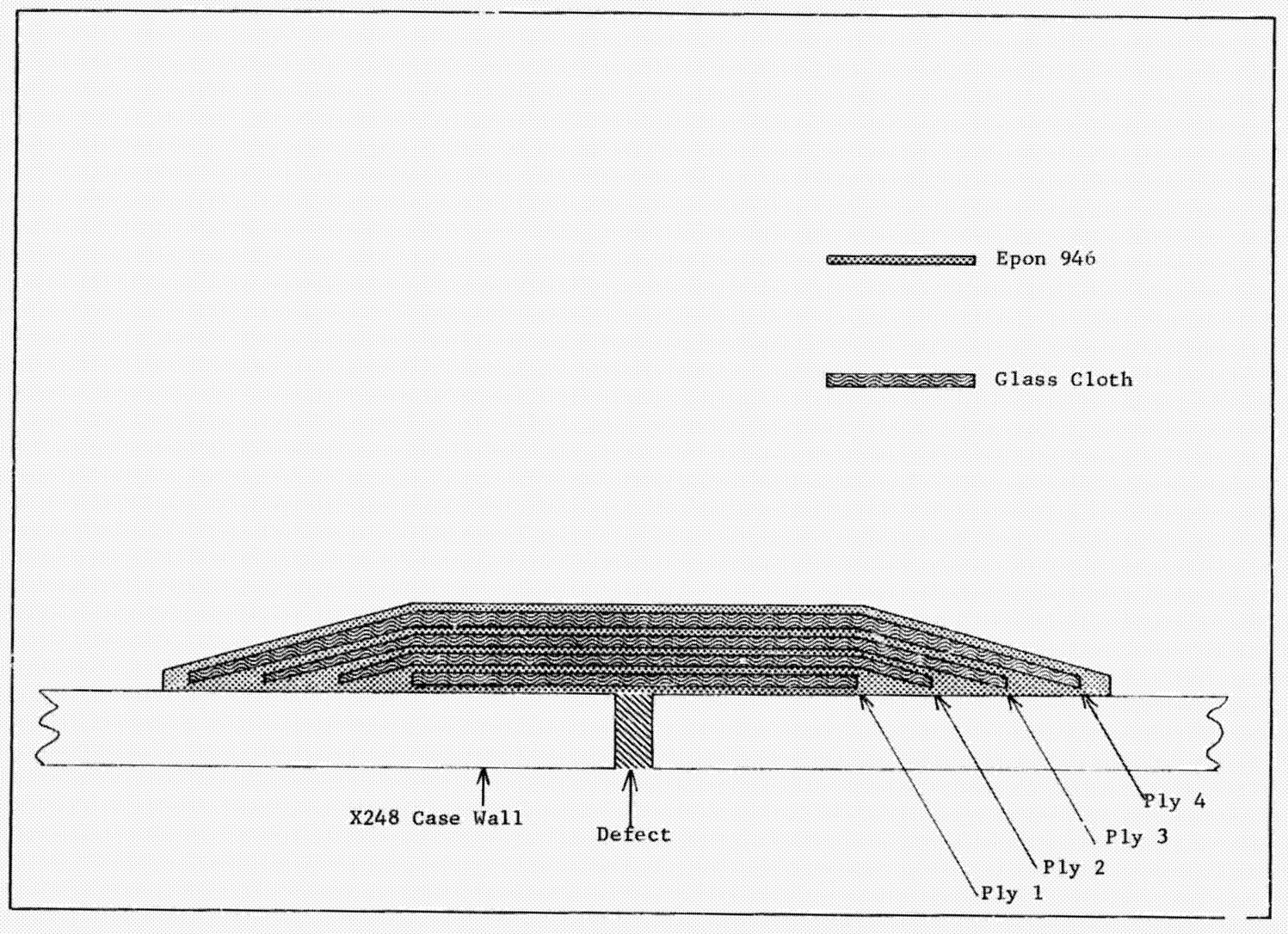


FIGURE 5 - OVERLAPPING PATCH TECHNIQUE

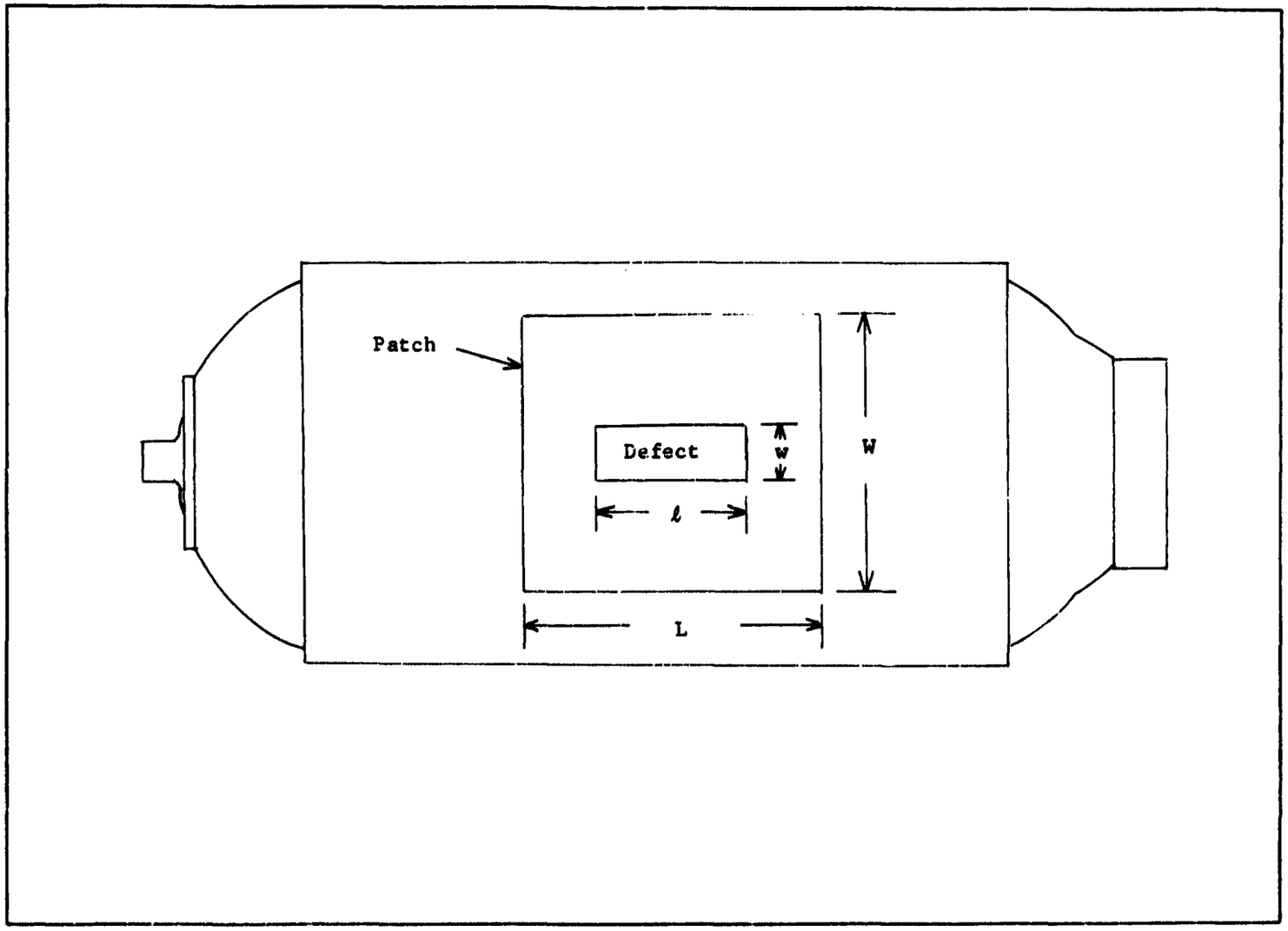
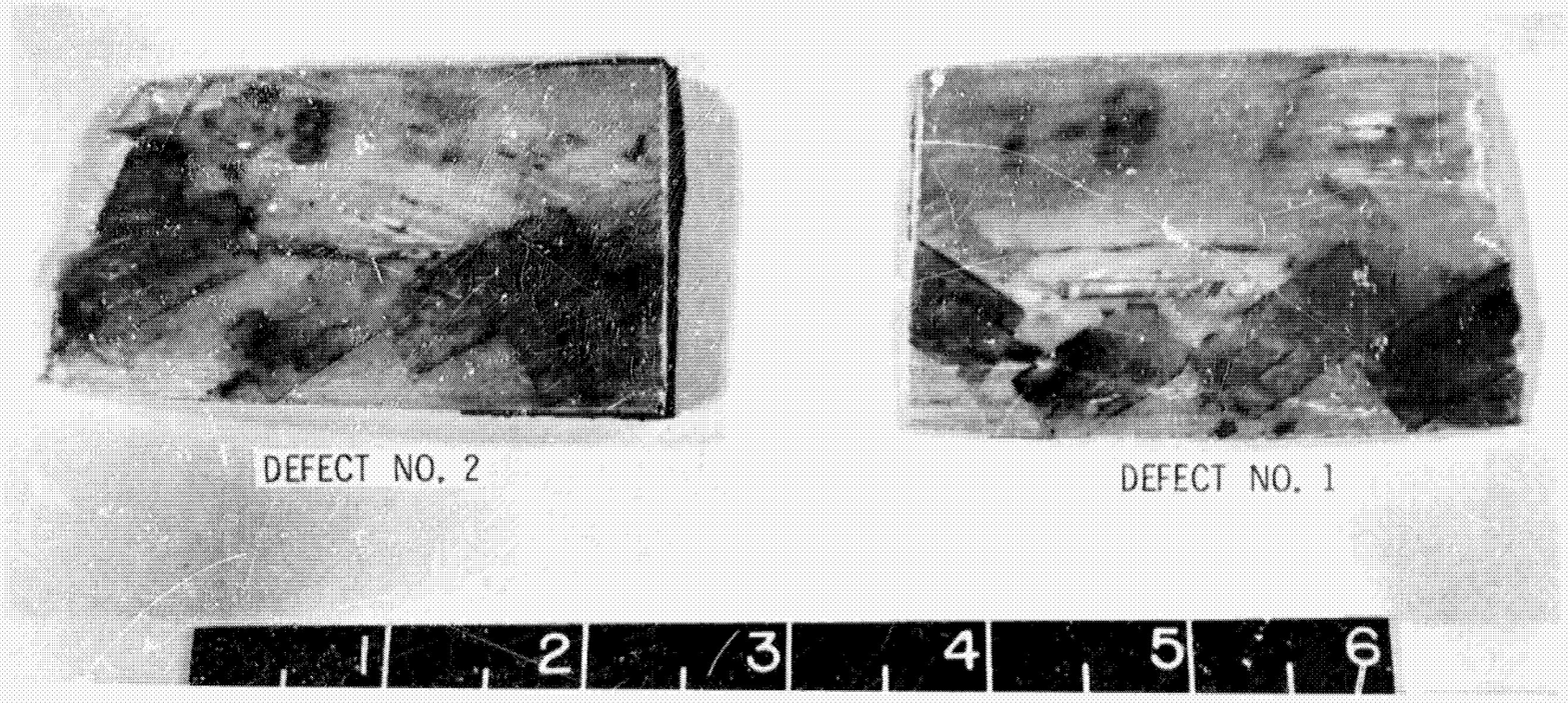


FIGURE 6 - DEFECT AND PATCH MEASUREMENT DEFINITIONS



G-2171

FIGURE 7 - TOP VIEW OF AFT DOME DEFECTS ON NPP-447 (A6)

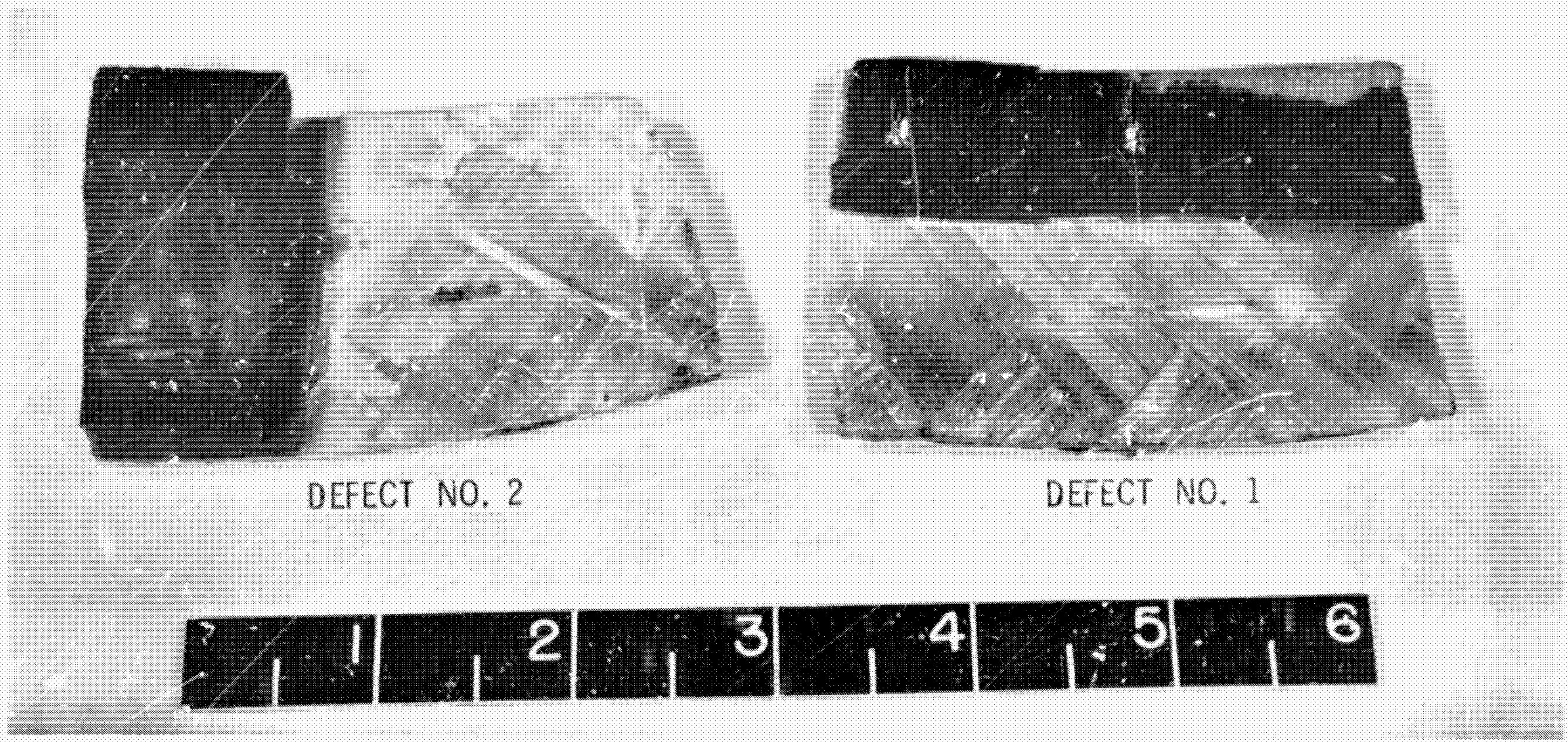
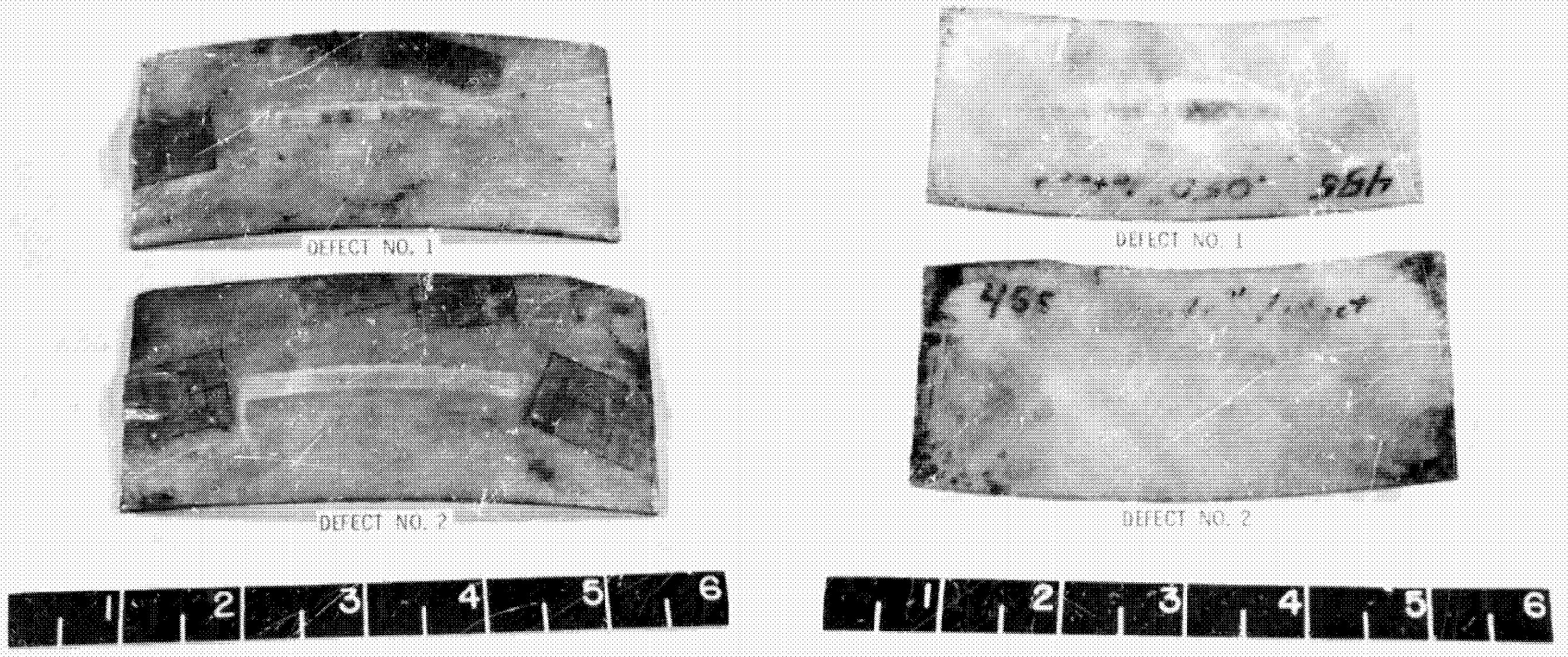


FIGURE 8 - UNDERSIDE VIEW OF AFT DOME DEFECTS ON NPP-447 (A6)

G-2173

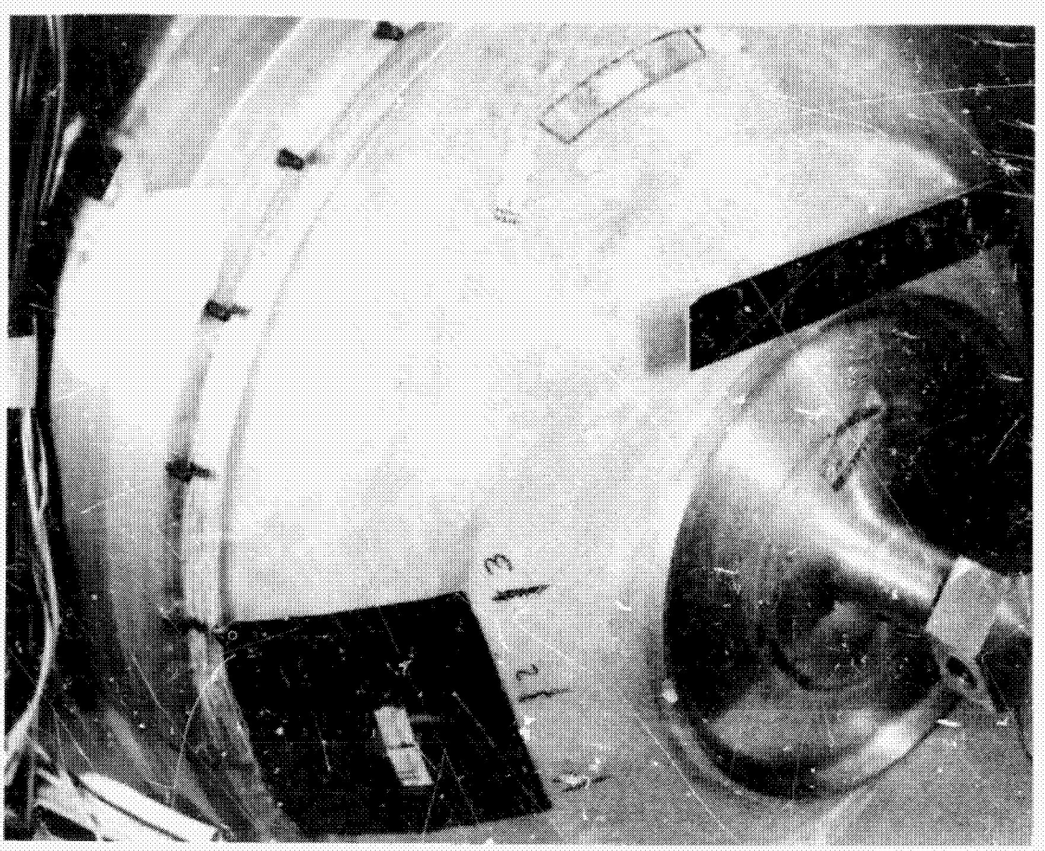


Top View

Underside View

G-2169

FIGURE 9 - FORWARD DOME DEFECTS ON NPP-455 (A6)



G-2170

FIGURE 10 - POST-FIRING VIEW OF FORWARD DOME DEFECTS ON NPP-454 (A6)

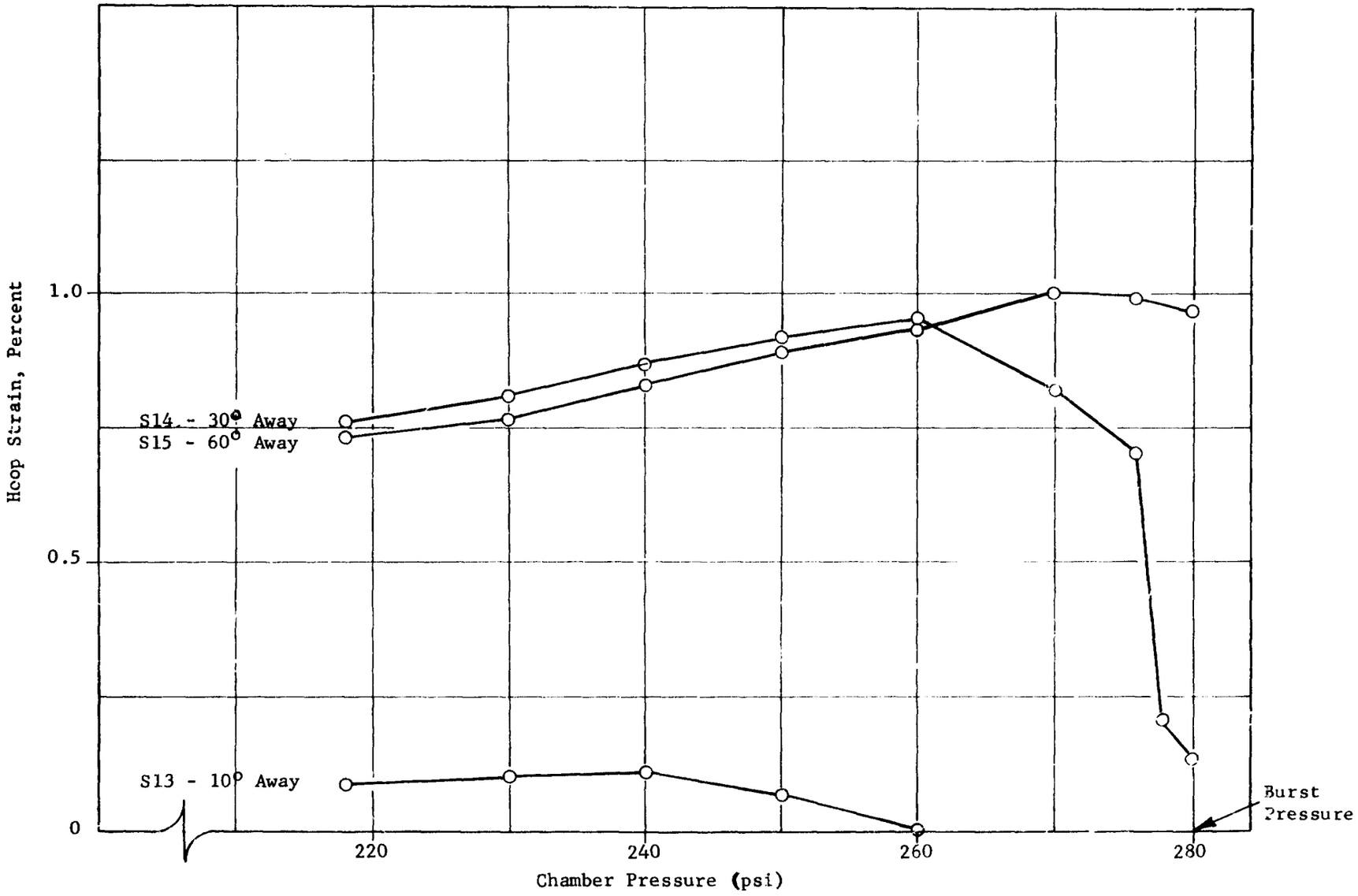


FIGURE 11 - PRESSURE VS. STRAIN FOR GAGES 10°, 30°, AND 60° AWAY FROM DEFECT NO. 2 FOR NPP-409 (A5) INDICATING PROGRESSIVE PEEL-BACK

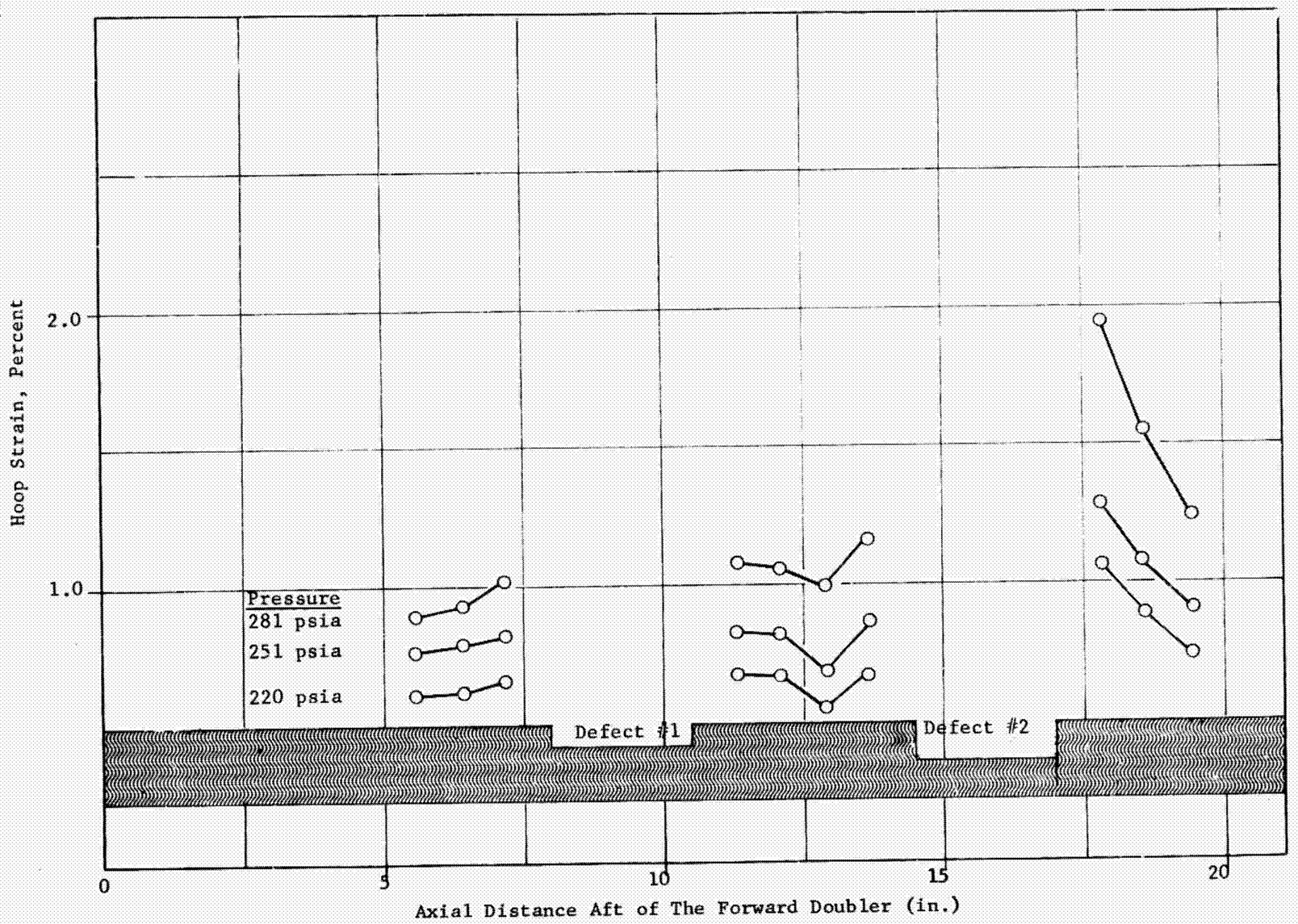
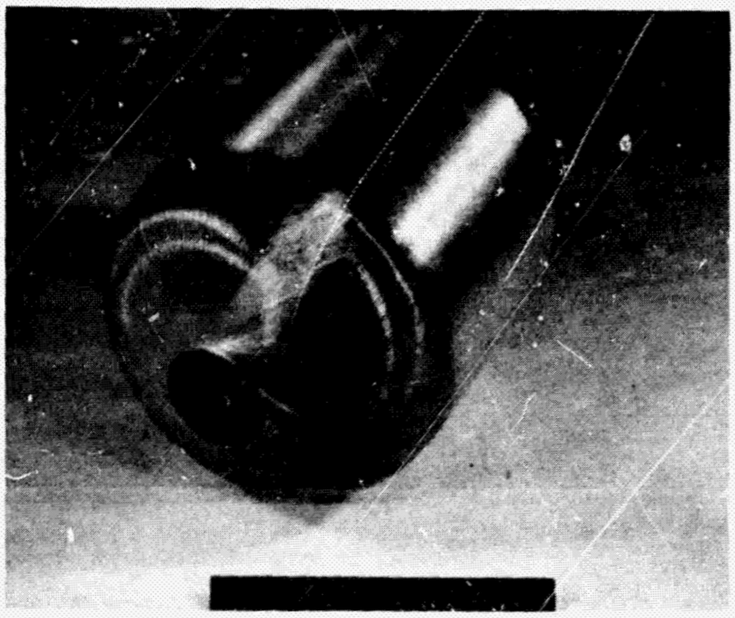


FIGURE 12 - STRAIN VS. PRESSURE ALONG THE CYLINDRICAL SECTION OF NPP-409 (A5)

G-2174

FIGURE 13 - CLOSE-UP OF PEEL-BACK AT DEFECT NO. 1 ON NPP-257 (A5)



G-2182

FIGURE 14 - FAILURE OF DEFECTED BOTTLE

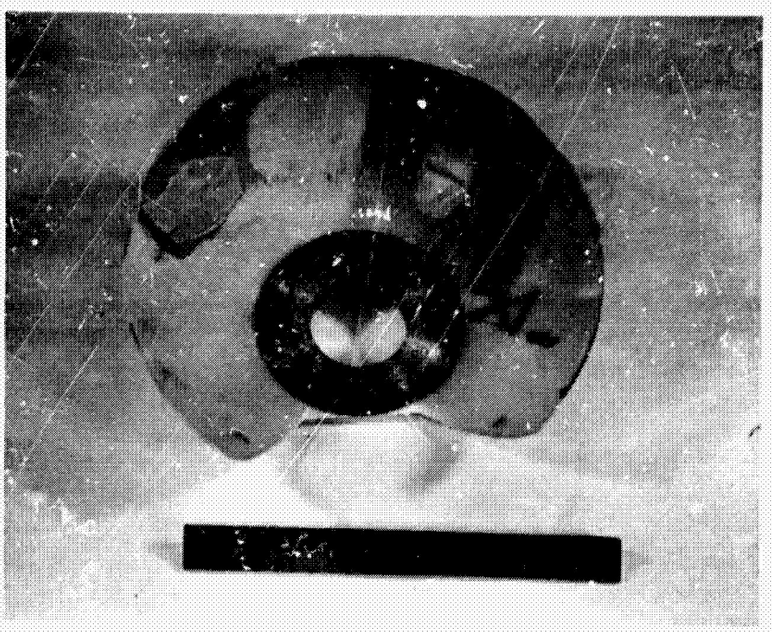
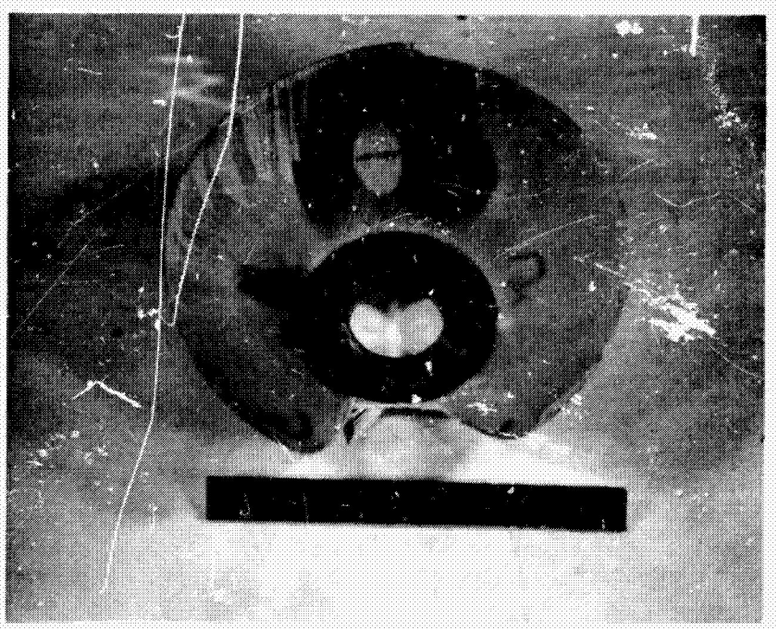


FIGURE 15 - UNDER SIDE OF TWO-PLY REPAIR OF PARTIAL DEFECT



G-2202

FIGURE 16 - UNDER SIDE OF THREE-PLY REPAIR OF PARTIAL DEFECT

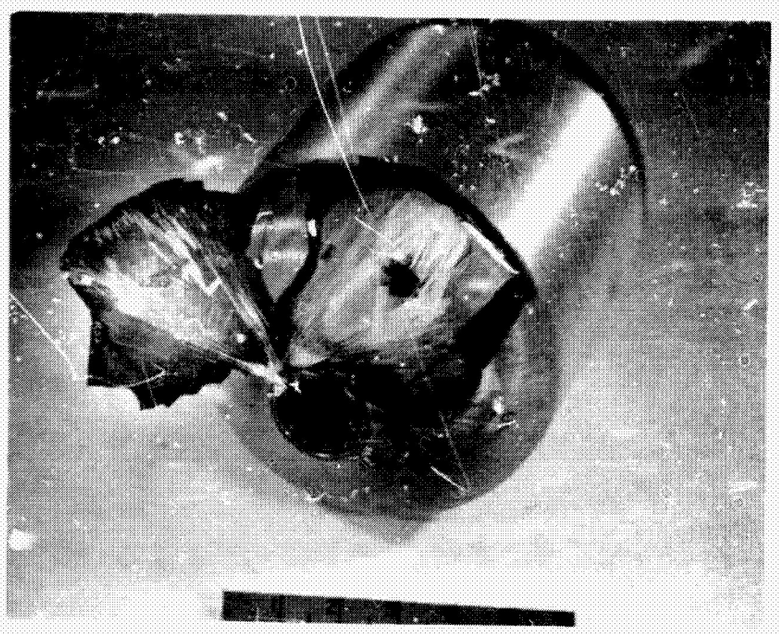


FIGURE 17 - SHEAR FAILURE OF BOTTLE S/N-19

G-2200

FIGURE 18 - TENSION FAILURE OF BOTTLE S/N-22

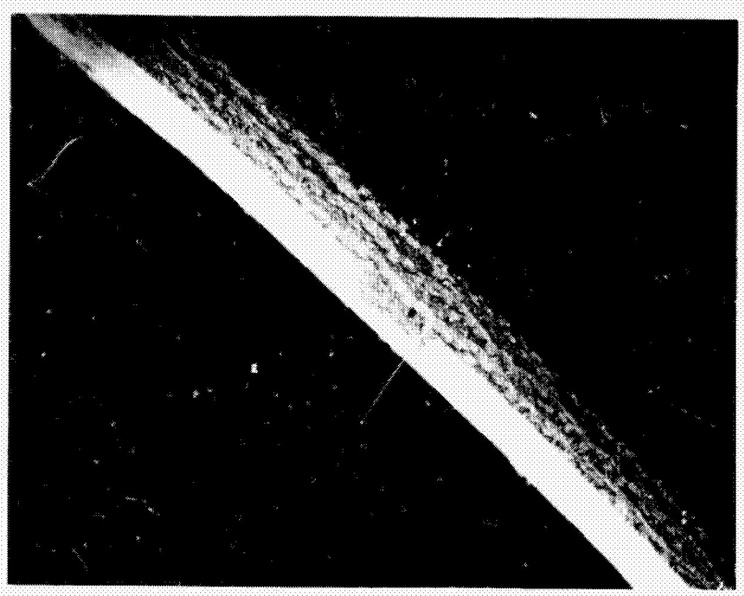


FIGURE 19 - CROSS SECTION OF DEFECT NO. 2 ON NPP-257 (A5)
MAGNIFICATION 5 TIMES

FIGURE 20 - CROSS SECTION OF DEFECT NO. 2 ON NPP-257 (A5)
MAGNIFICATION 10 TIMES

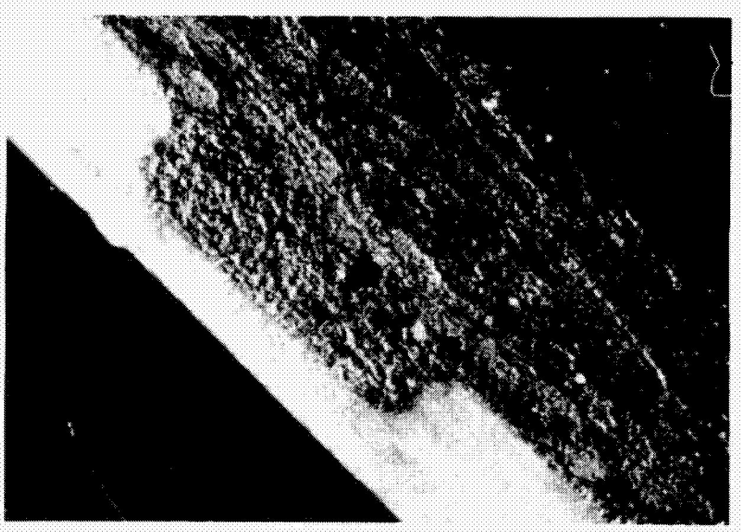


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FIGURE 21 - CROSS SECTION OF DEFECT NO. 2 ON NPP-257 (A5)
MAGNIFICATION 20 TIMES

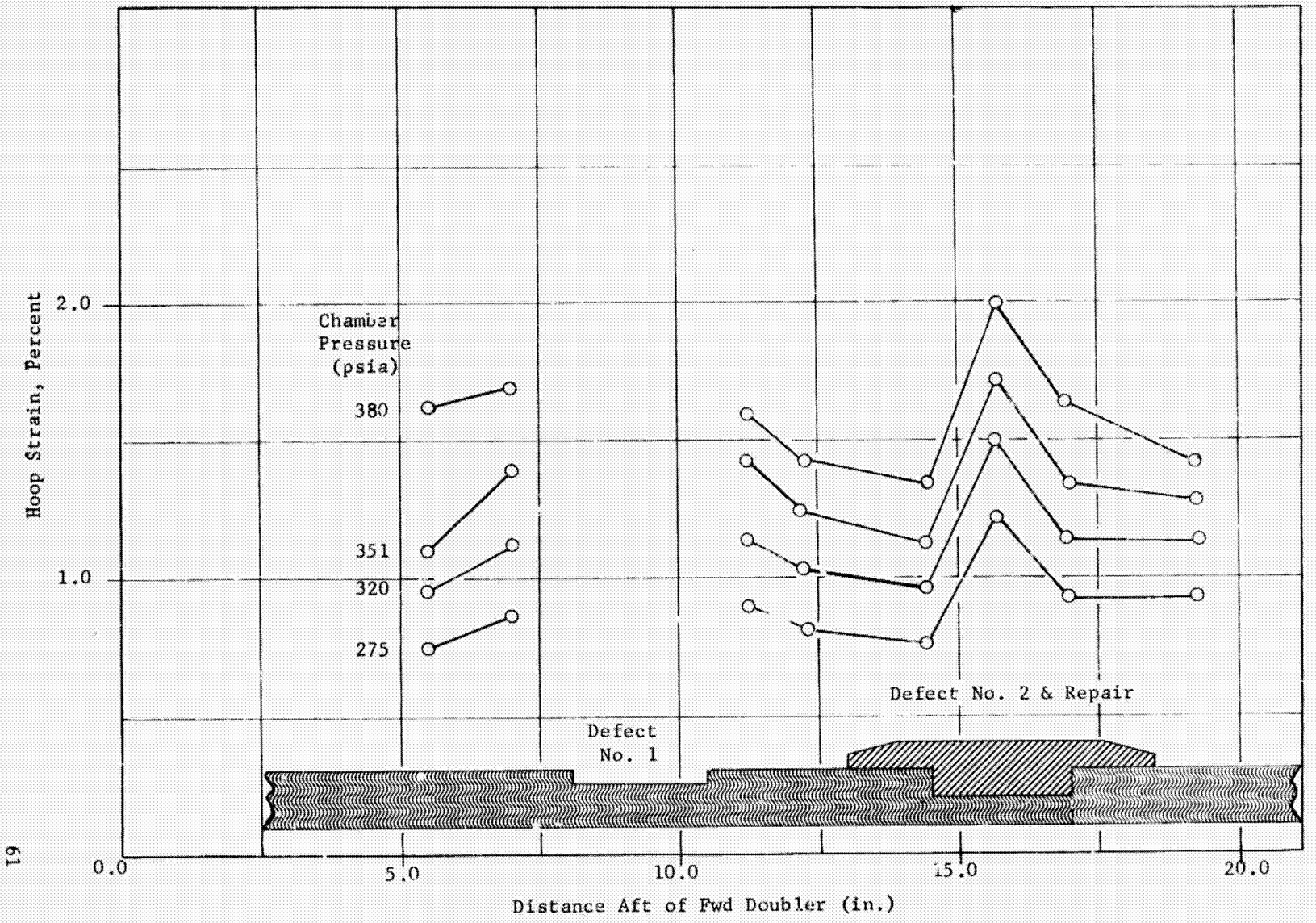


FIGURE 22 - HOOP STRAIN VS. PRESSURE FOR S/N NPP-257 (A5)

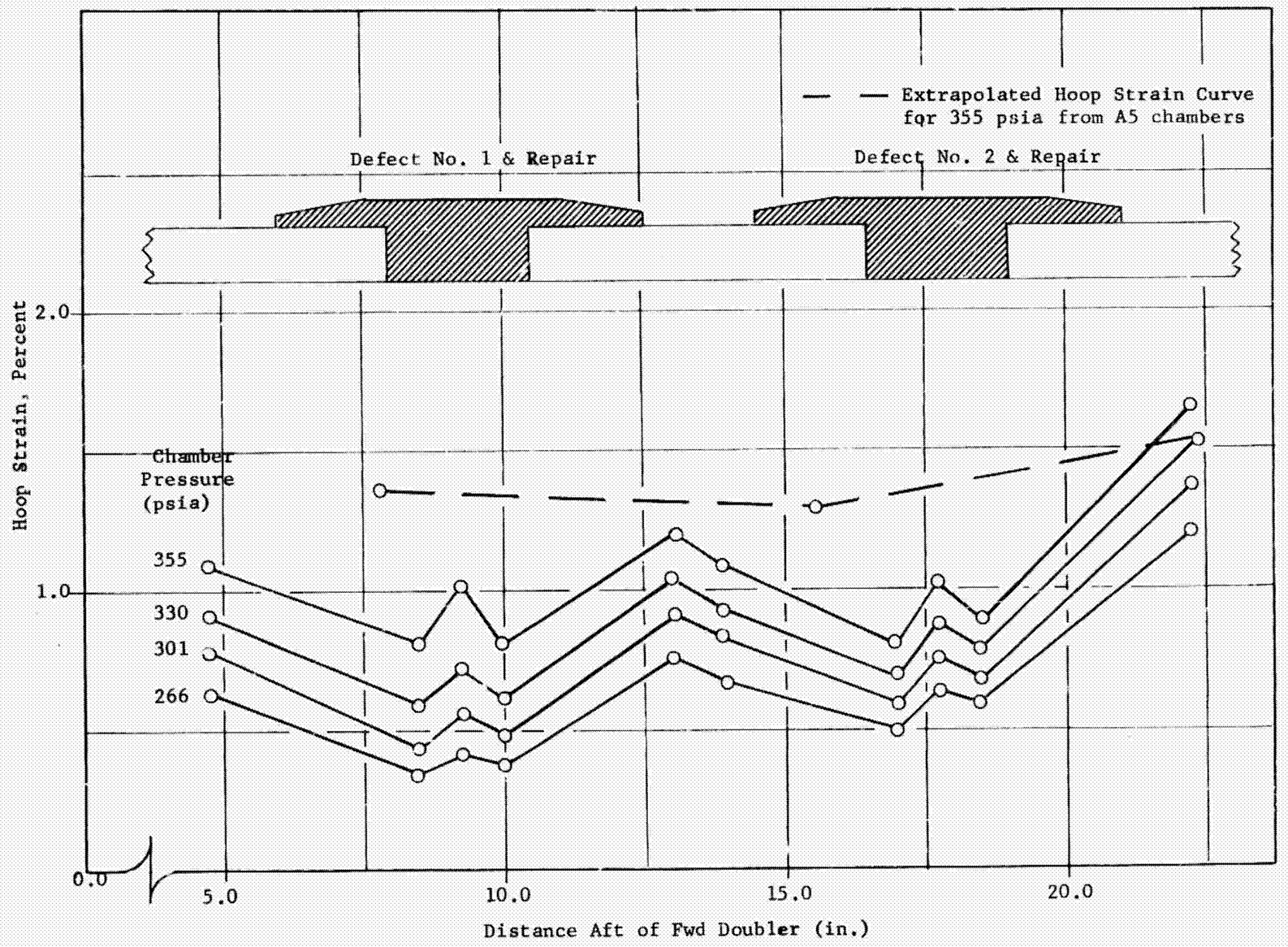


FIGURE 23 - HOOP STRAIN VS. LOCATION AND PRESSURE X248 S/N NPP-261 (A5)

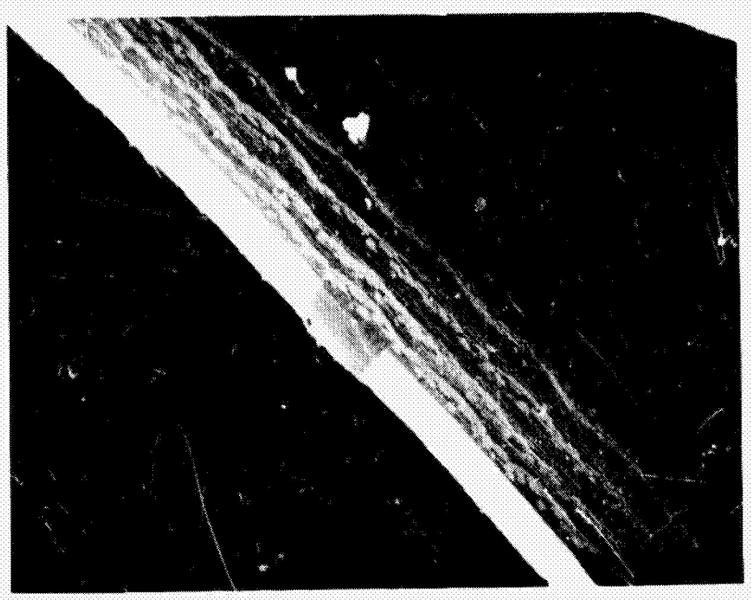


FIGURE 24 - CROSS SECTION OF DEFECT AND PATCH ON NPP-261 (A5)
MAGNIFICATION 5 TIMES

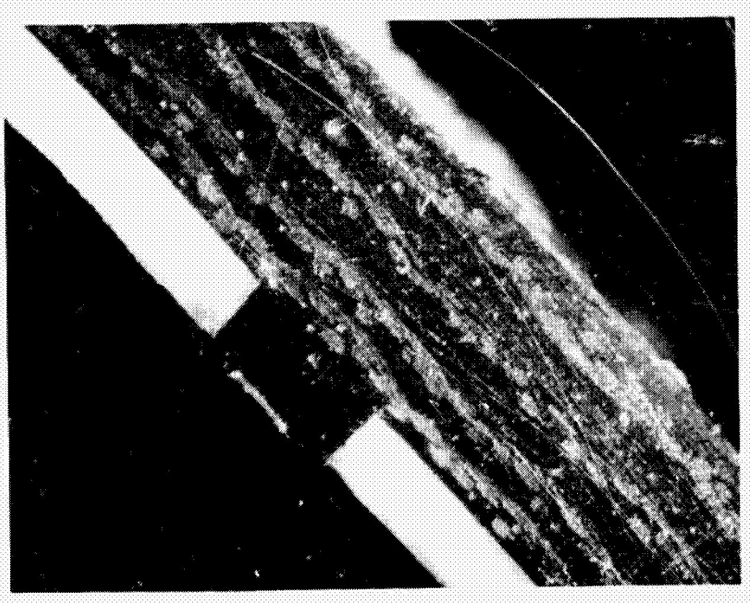


FIGURE 25 - CROSS SECTION OF DEFECT AND REPAIR ON NPP-261 (A5)
MAGNIFICATION 10 TIMES

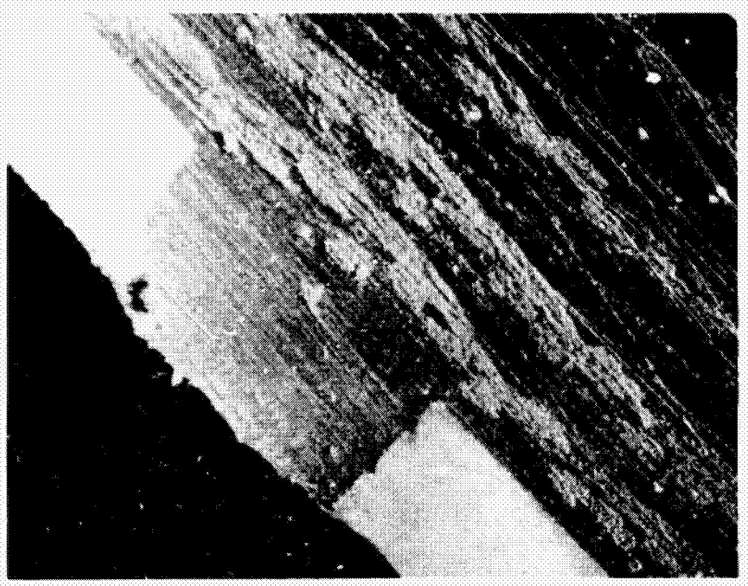


FIGURE 26 - CROSS SECTION OF DEFECT AND PATCH ON NPP-261 (A5)
MAGNIFICATION 20 TIMES

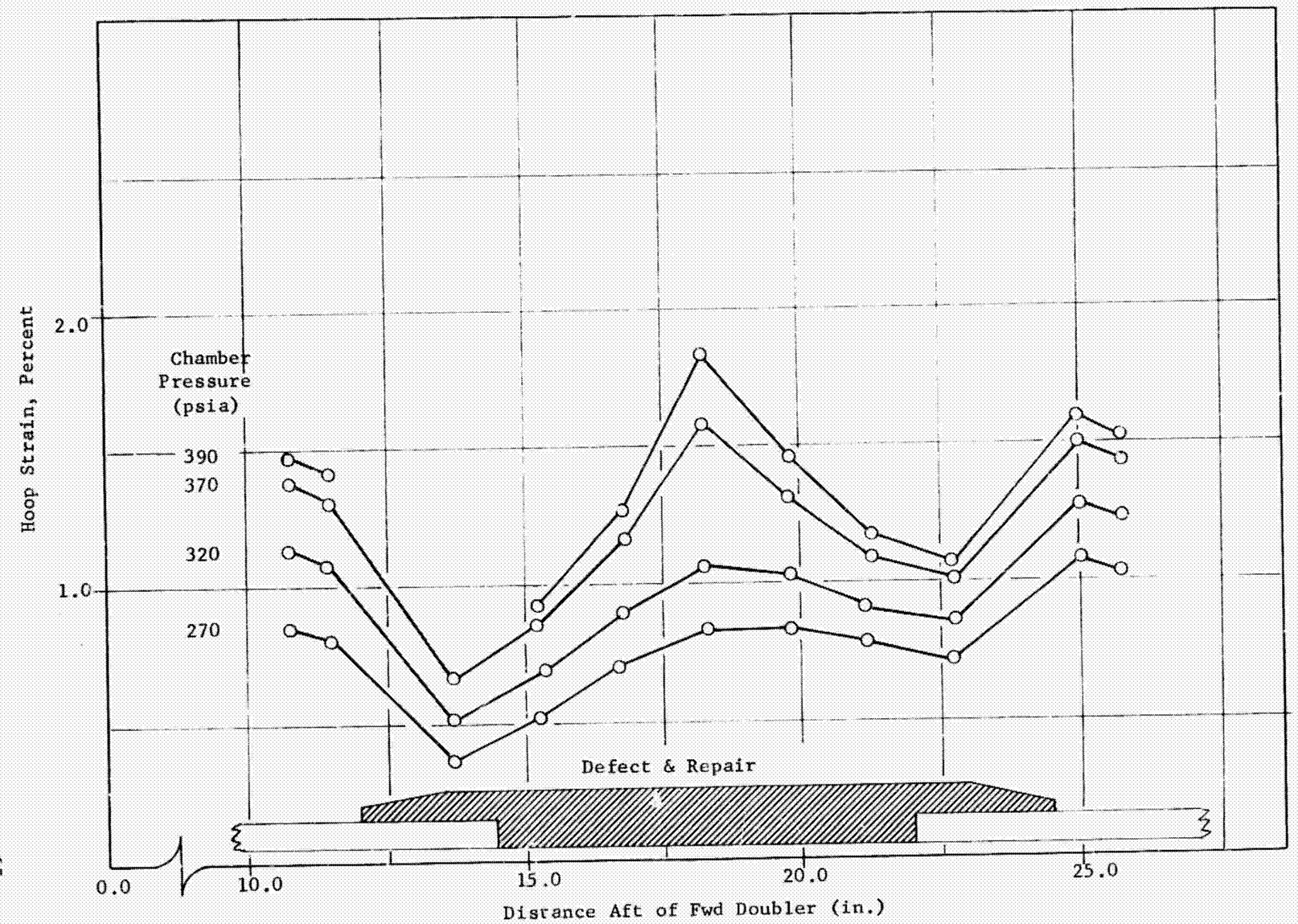
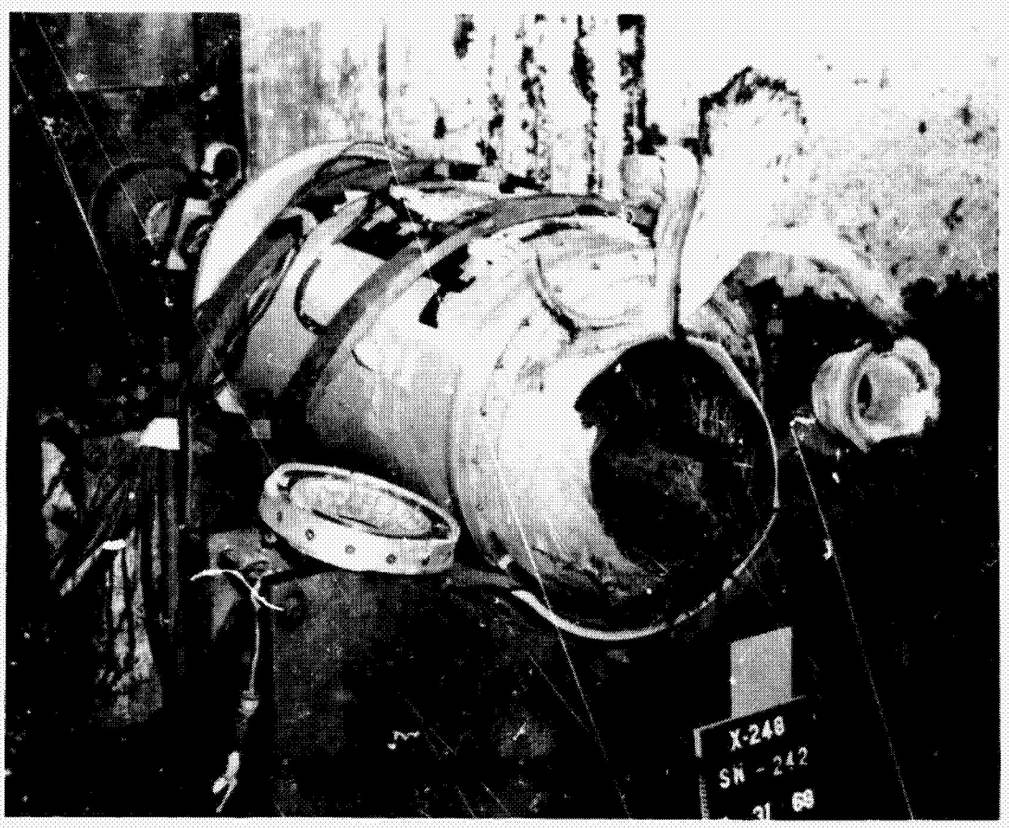


FIGURE 27 - HOOP STRAIN VS. LOCATION AND PRESSURE X248 S/N NPP-242 (A5)



8-2196

FIGURE 28 - POST-FIRING VIEW OF AFT END FAILURE OF NPP-242 (A5)

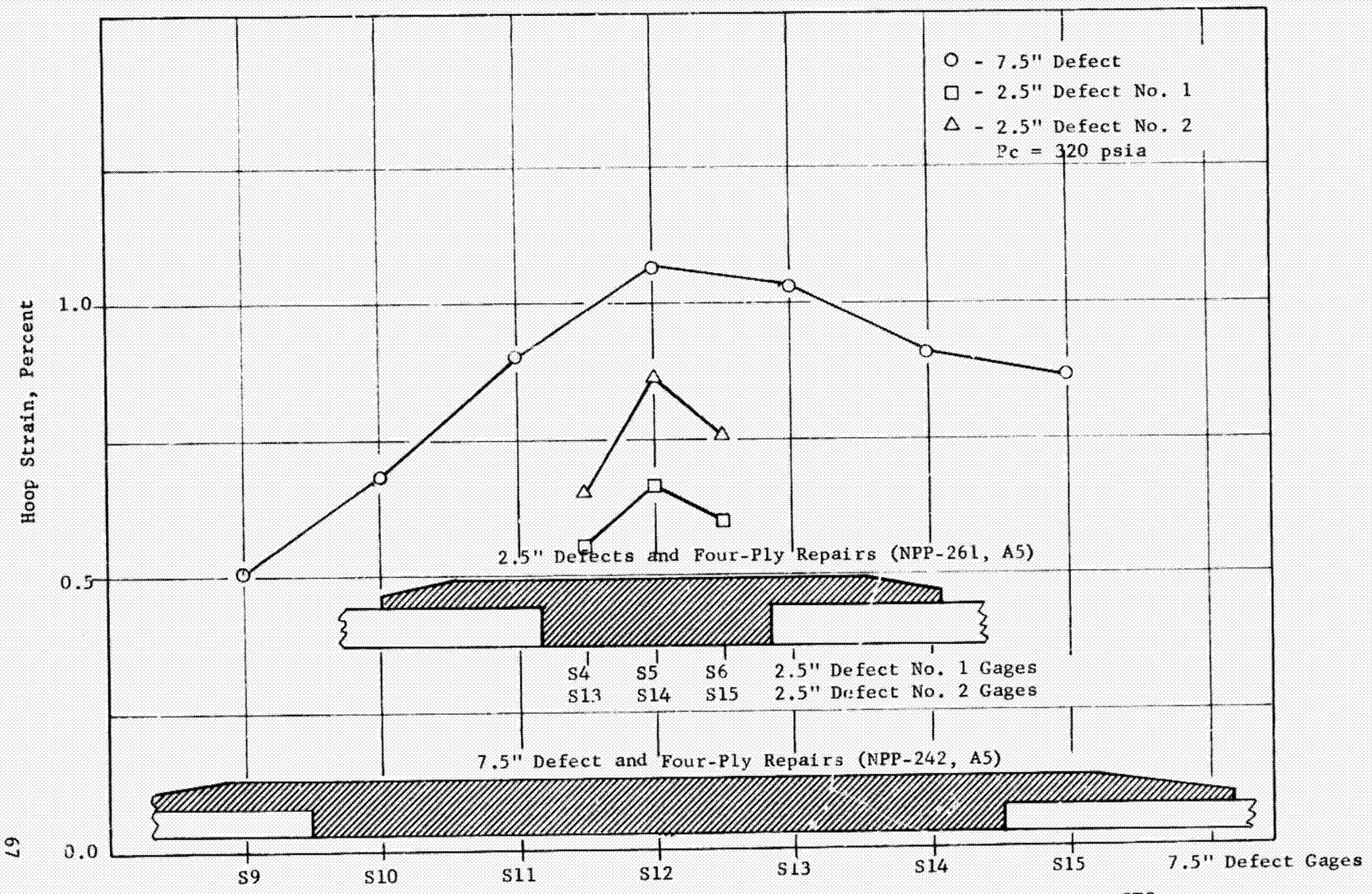


FIGURE 29 - COMPARISON OF 2.5 INCH AND 7.5 INCH LONGITUDINAL DEFECTS

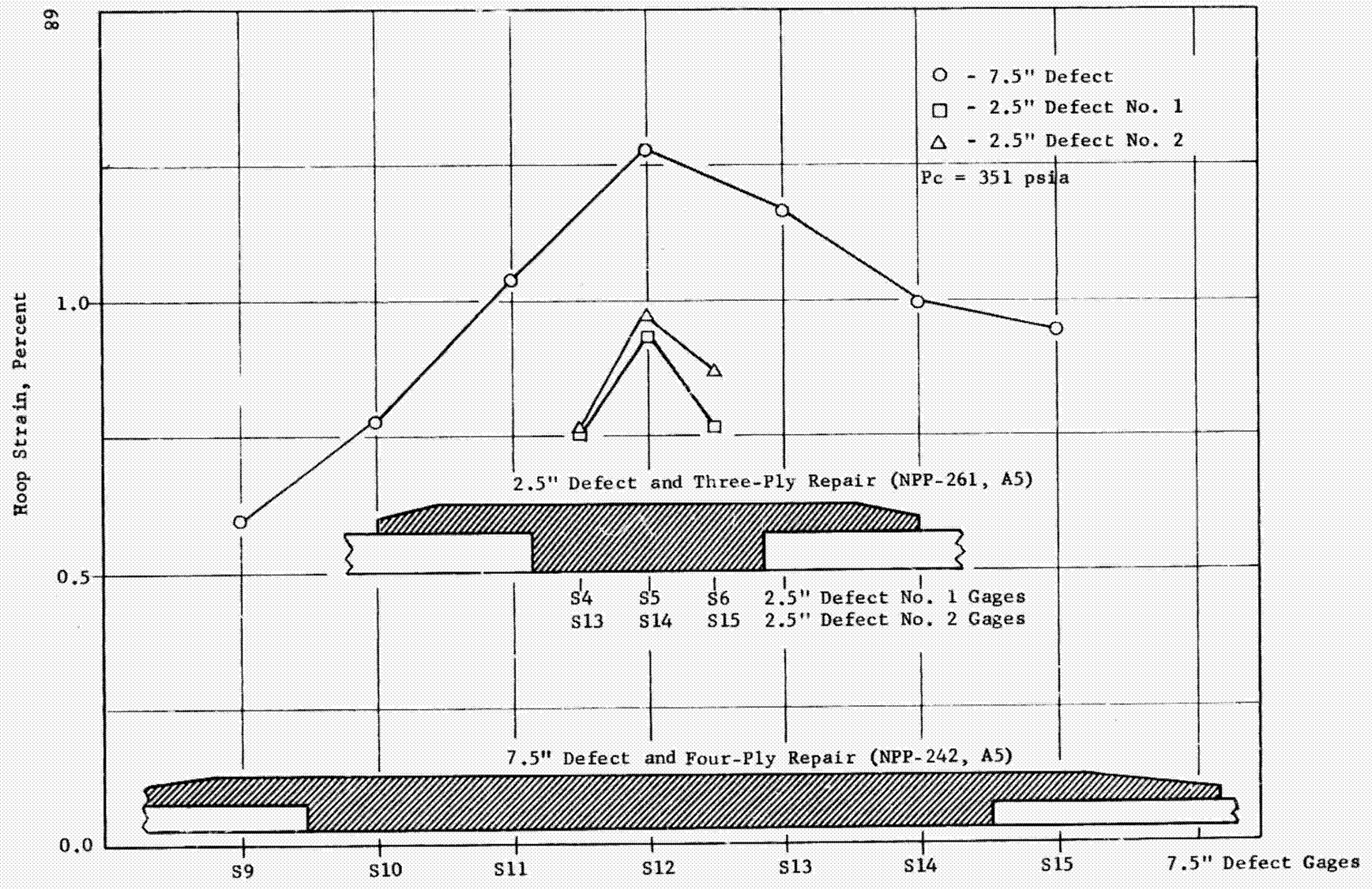


FIGURE 30 - COMPARISON OF 2.5 INCH AND 7.5 INCH LONGITUDINAL DEFECTS

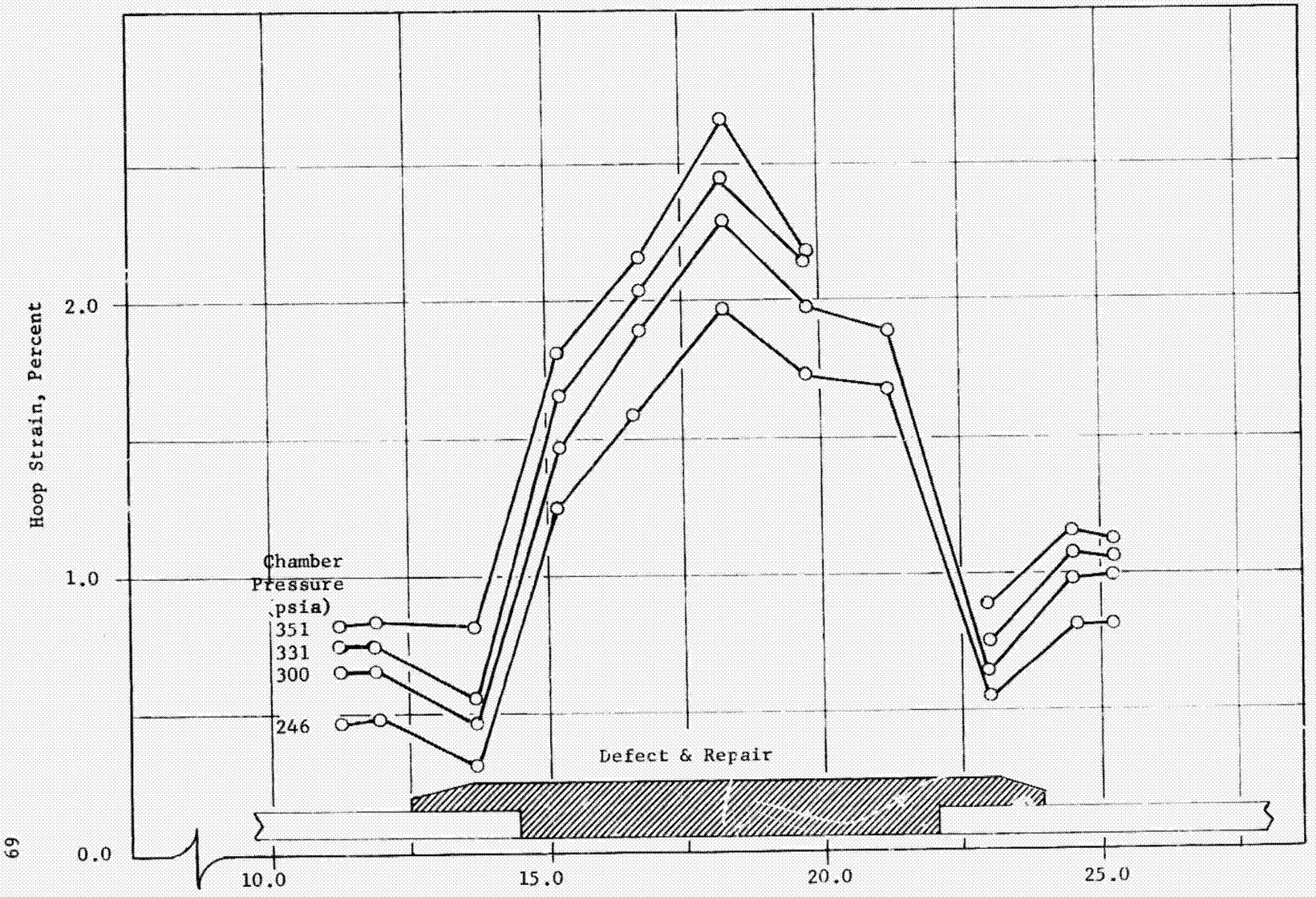
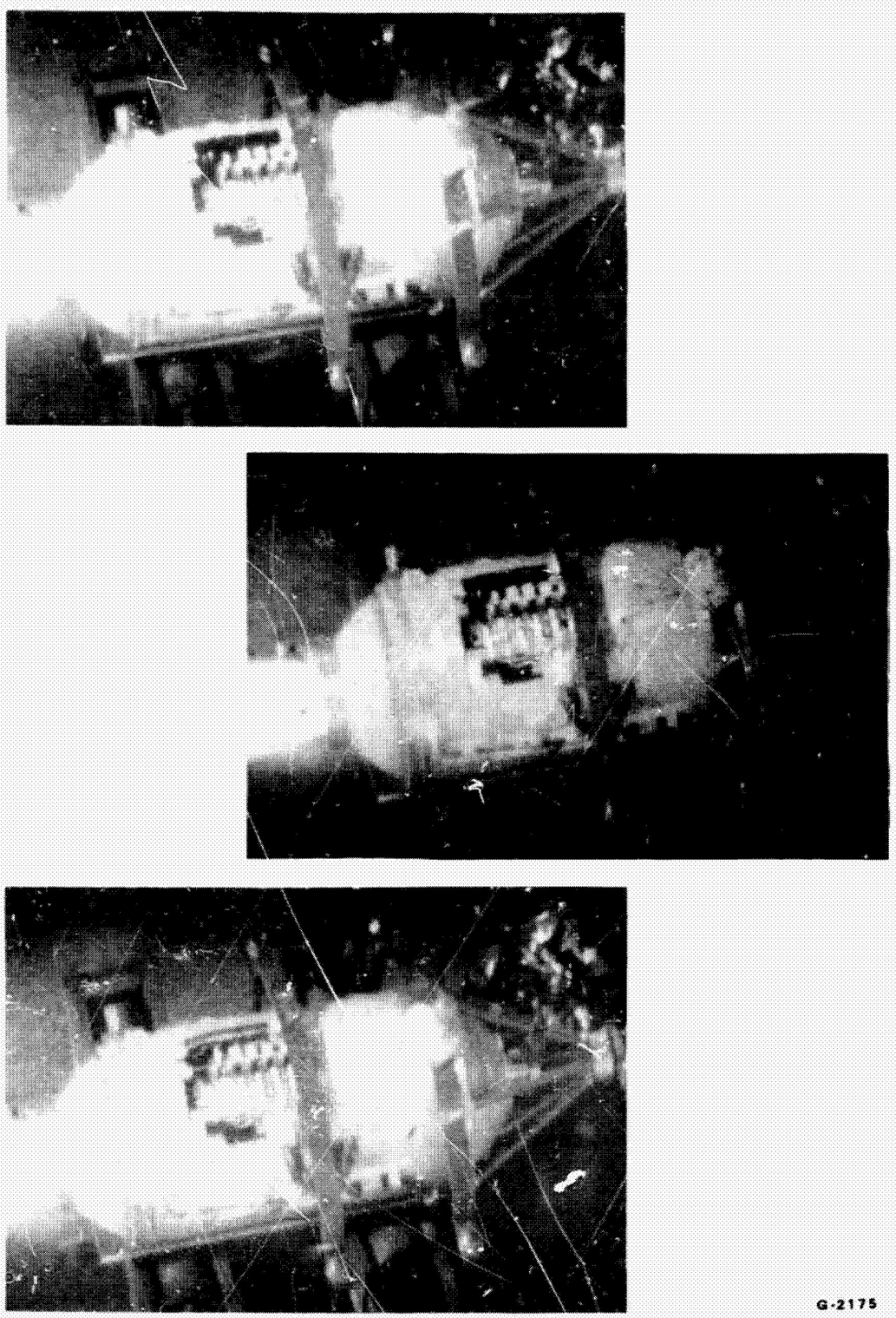


FIGURE 31 - HOOP STRAIN VS. LOCATION AND PRESSURE X248 S/N NPP-475 (A6)

FIGURE 32 A - TOP VIEW OF PATCH REPAIR ON NPP-475 (A6)

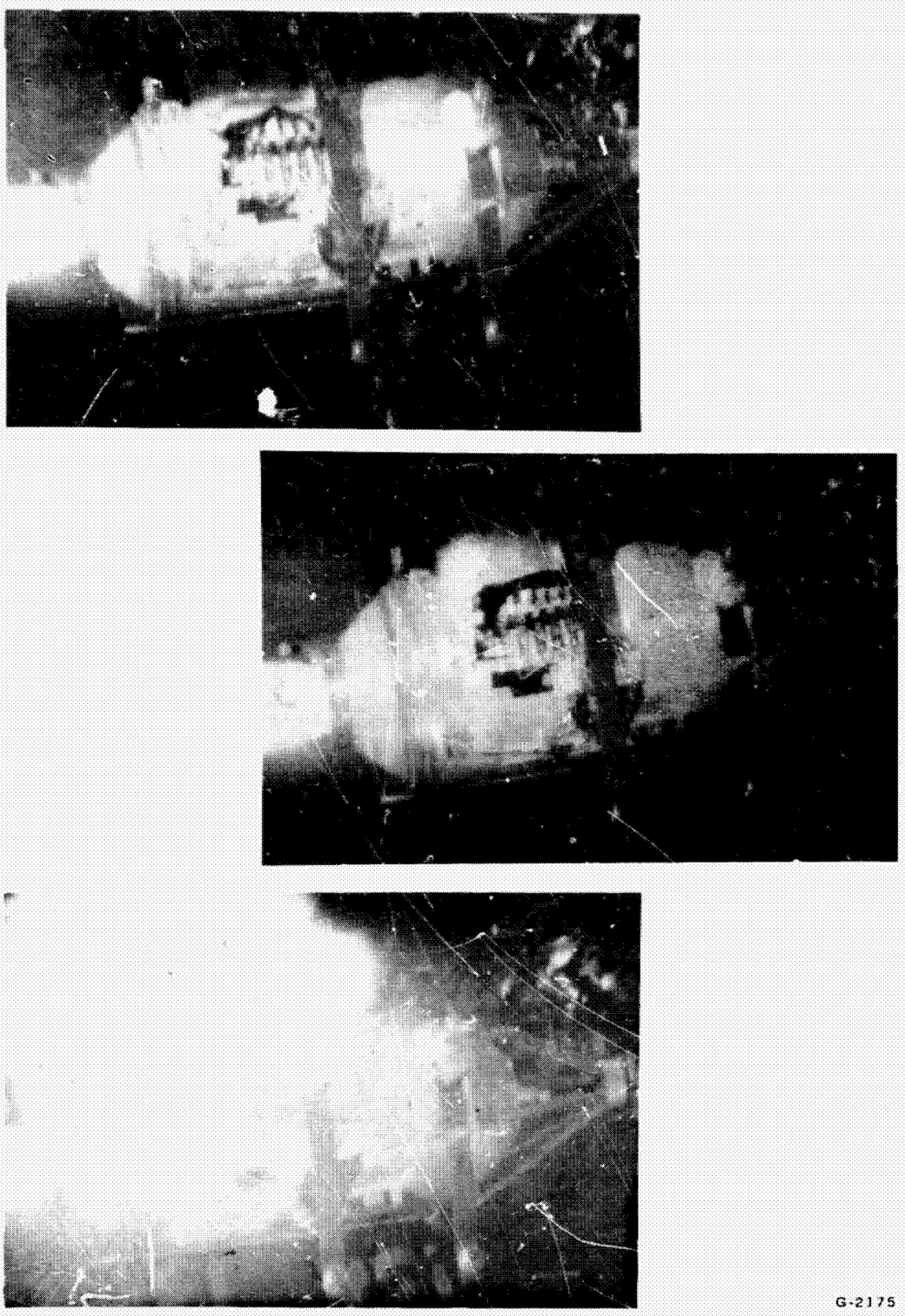
FIGURE 32B - BOTTOM VIEW OF PATCH REPAIR OF NPP-475 (A6)

G-2330



G-2175

FIGURE 33 - MOTION PICTURES OF S/N 475 (A6) FAILURE



G-2175

FIGURE 33 - MOTION PICTURES OF S/N 475 (A6) FAILURE

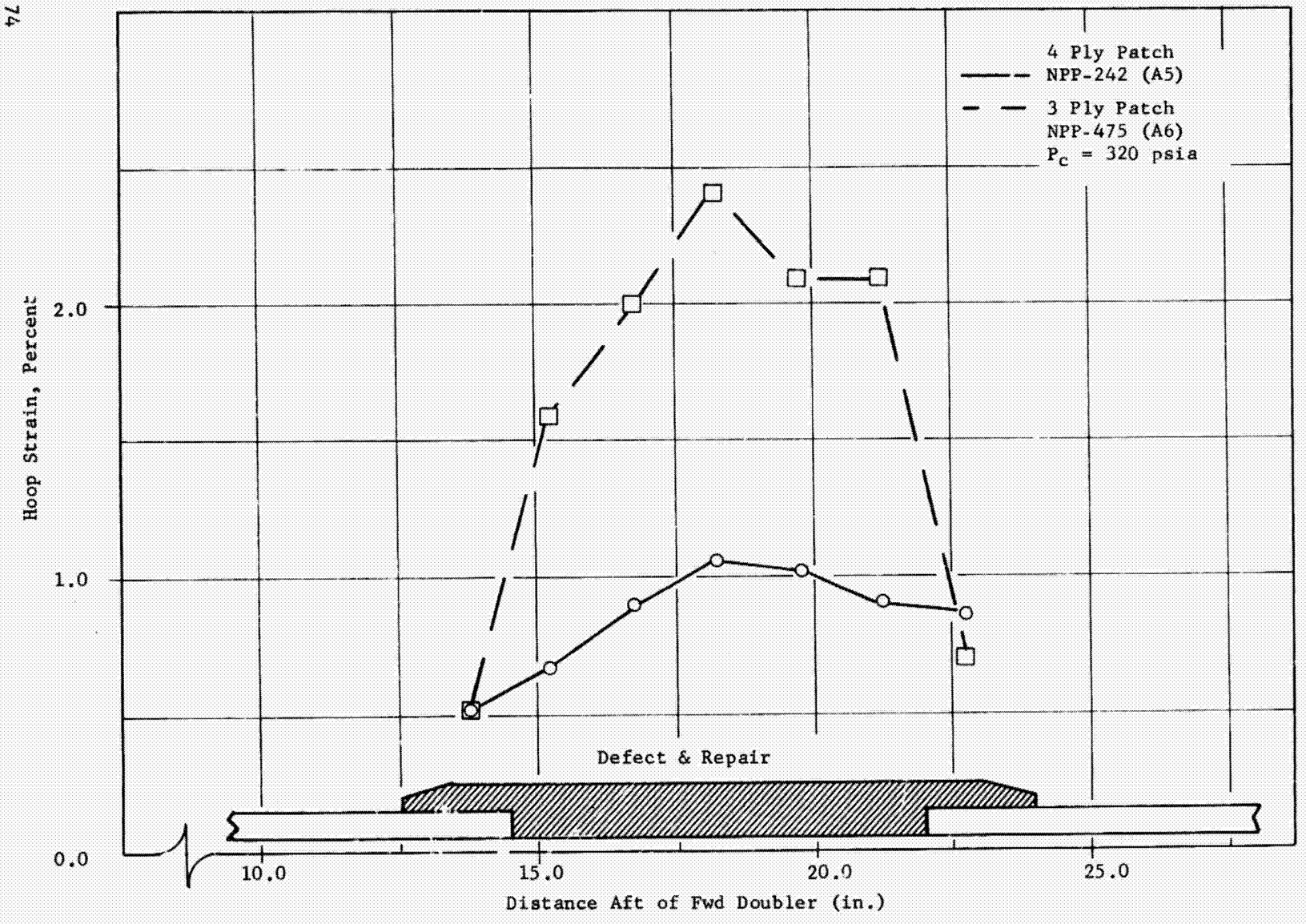


FIGURE 34 - COMPARISON OF THREE AND FOUR PLY PATCHES

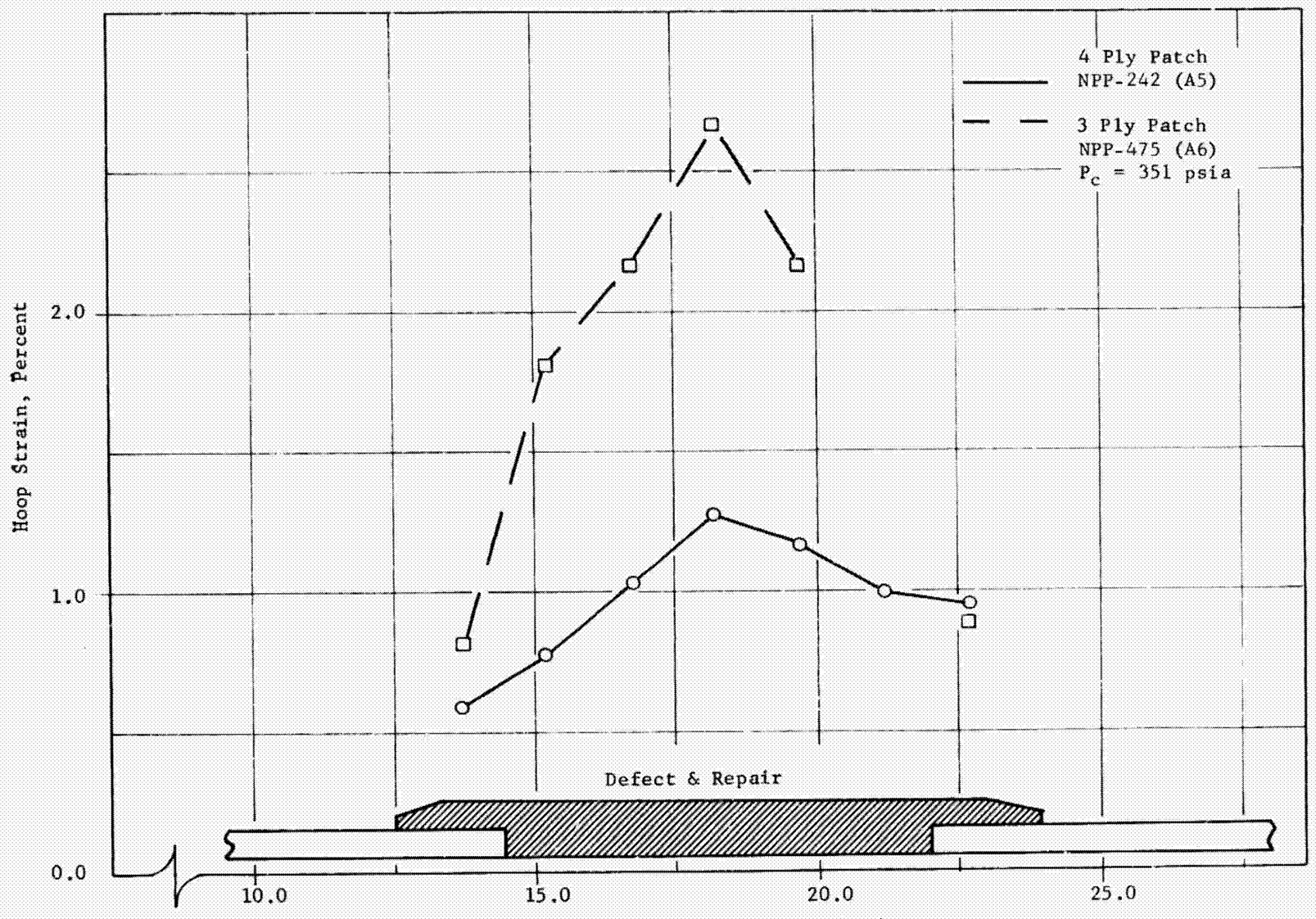
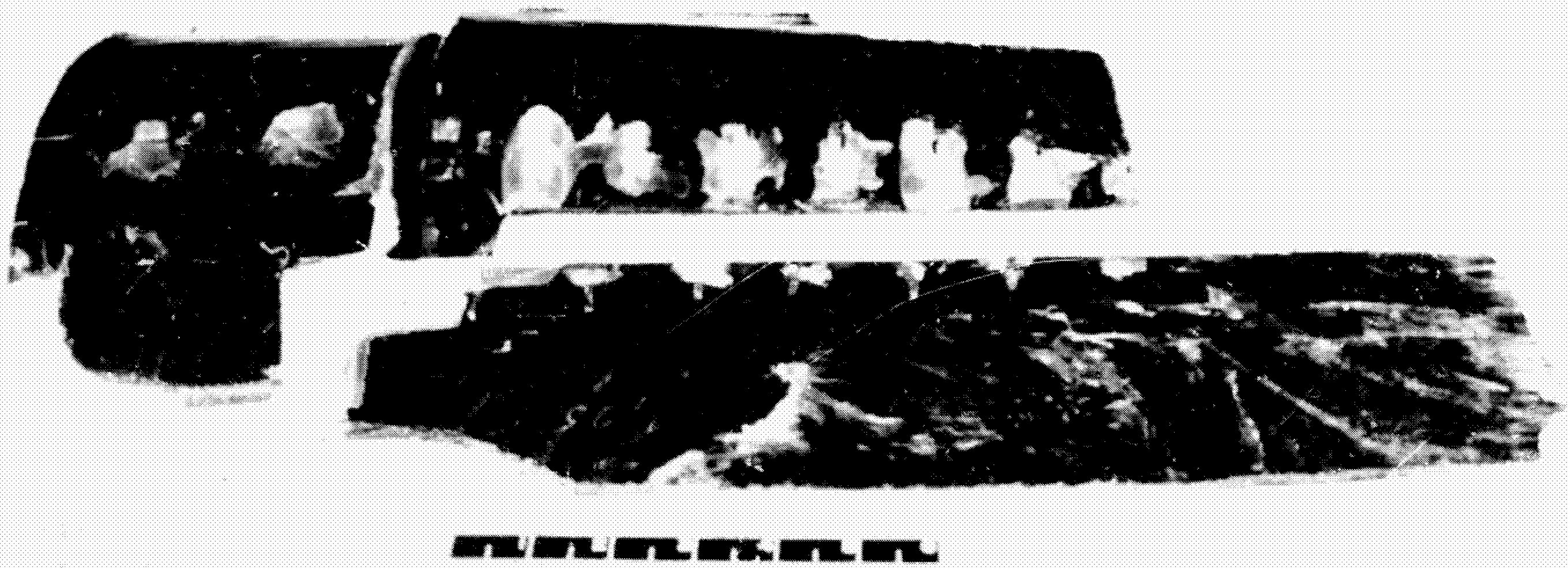
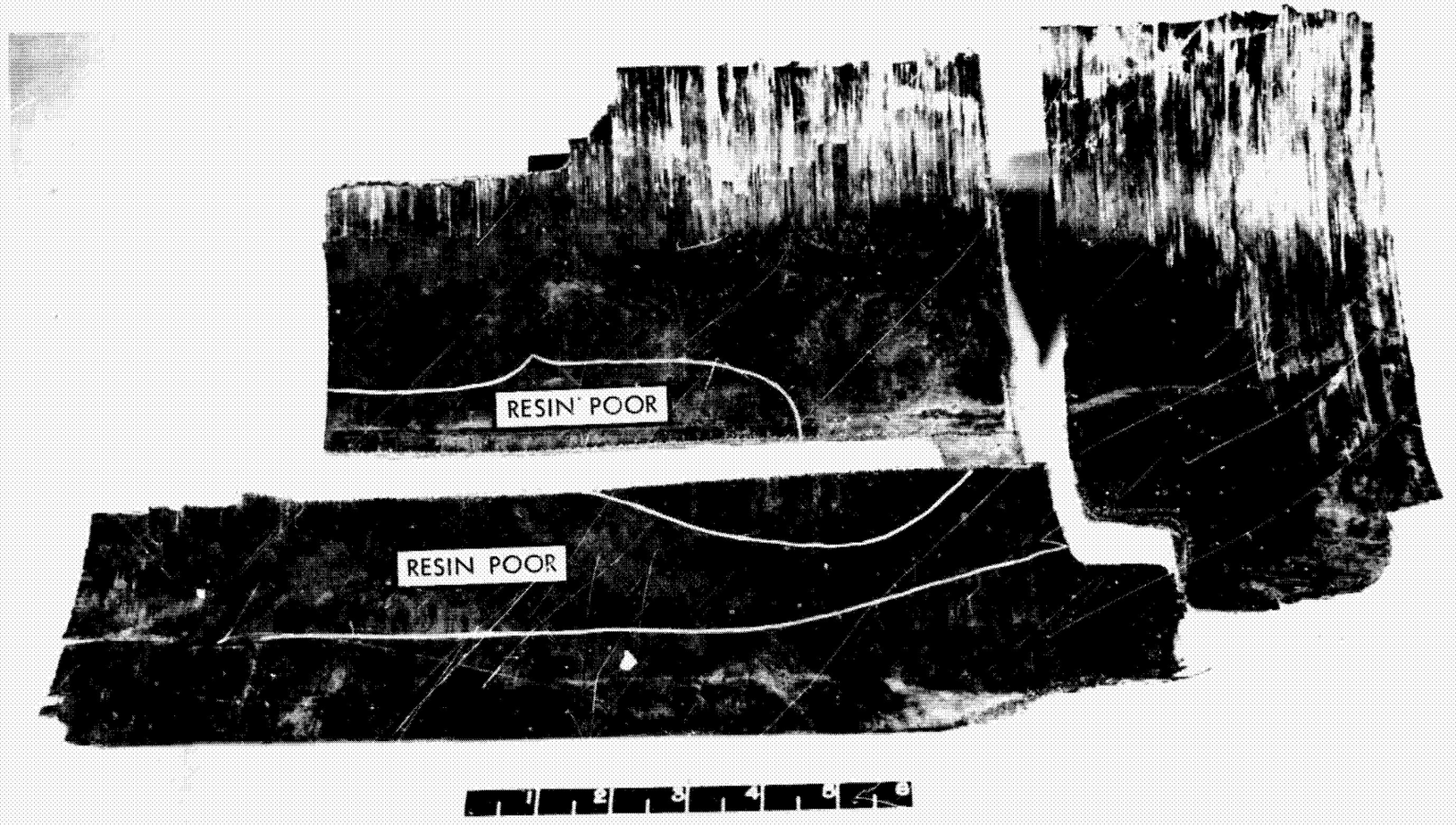


FIGURE 35 - COMPARISON OF THREE AND FOUR PLY PATCHES



G-2188

FIGURE 36A - TOP VIEW OF PATCH REPAIR ON NPP-425 (A6)



G-2331

FIGURE 36B - BOTTOM VIEW OF PATCH REPAIR ON NPP-425 (A6)

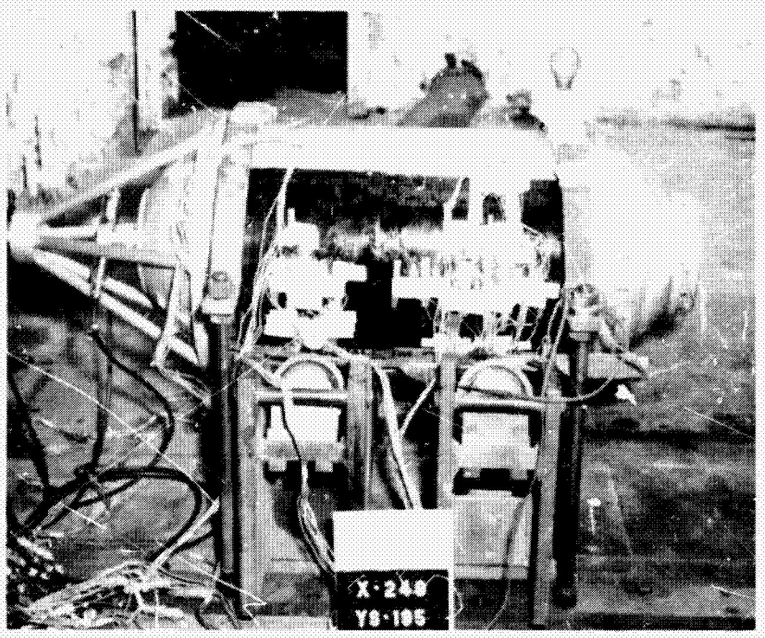


FIGURE 37A - PRE-FIRING PICTURE OF Y-195 (A10)

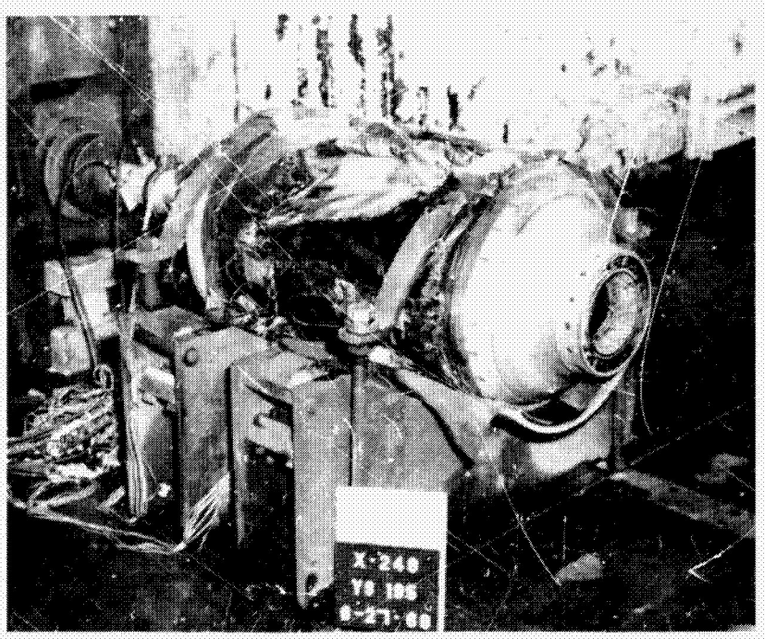
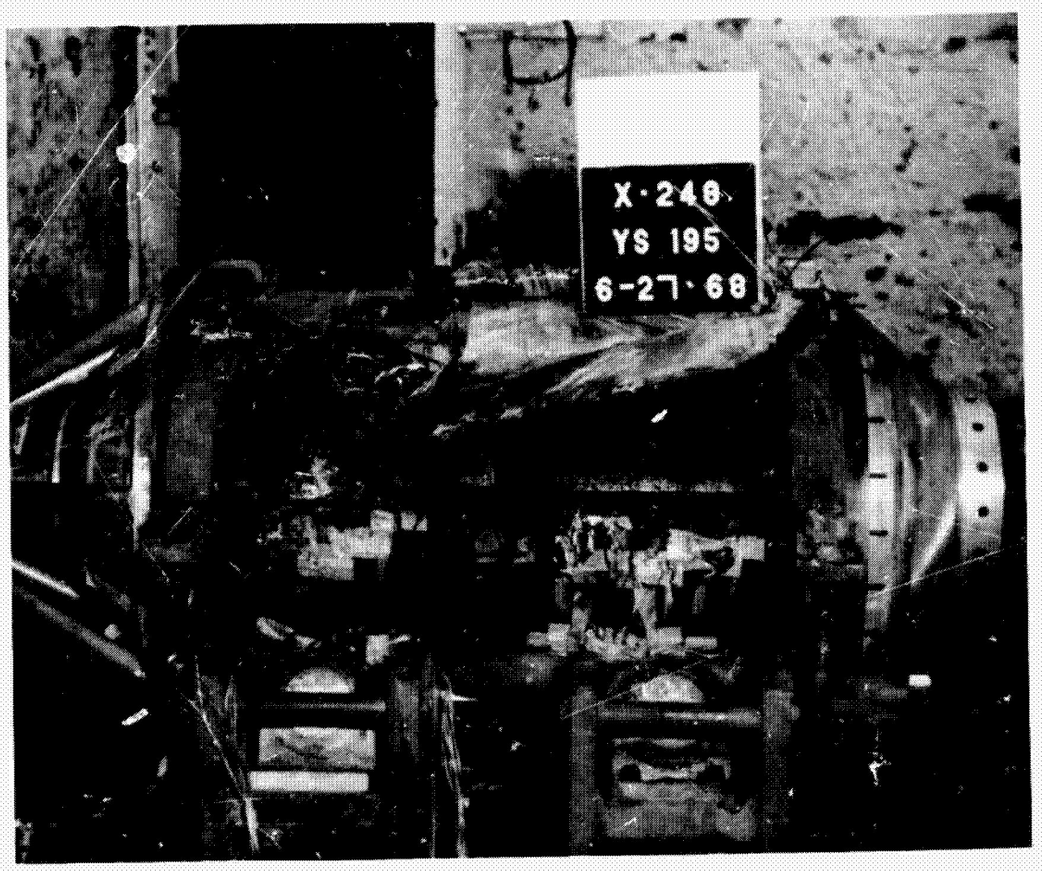


FIGURE 37B - POST-FIRING PICTURE OF Y-195 (A10)

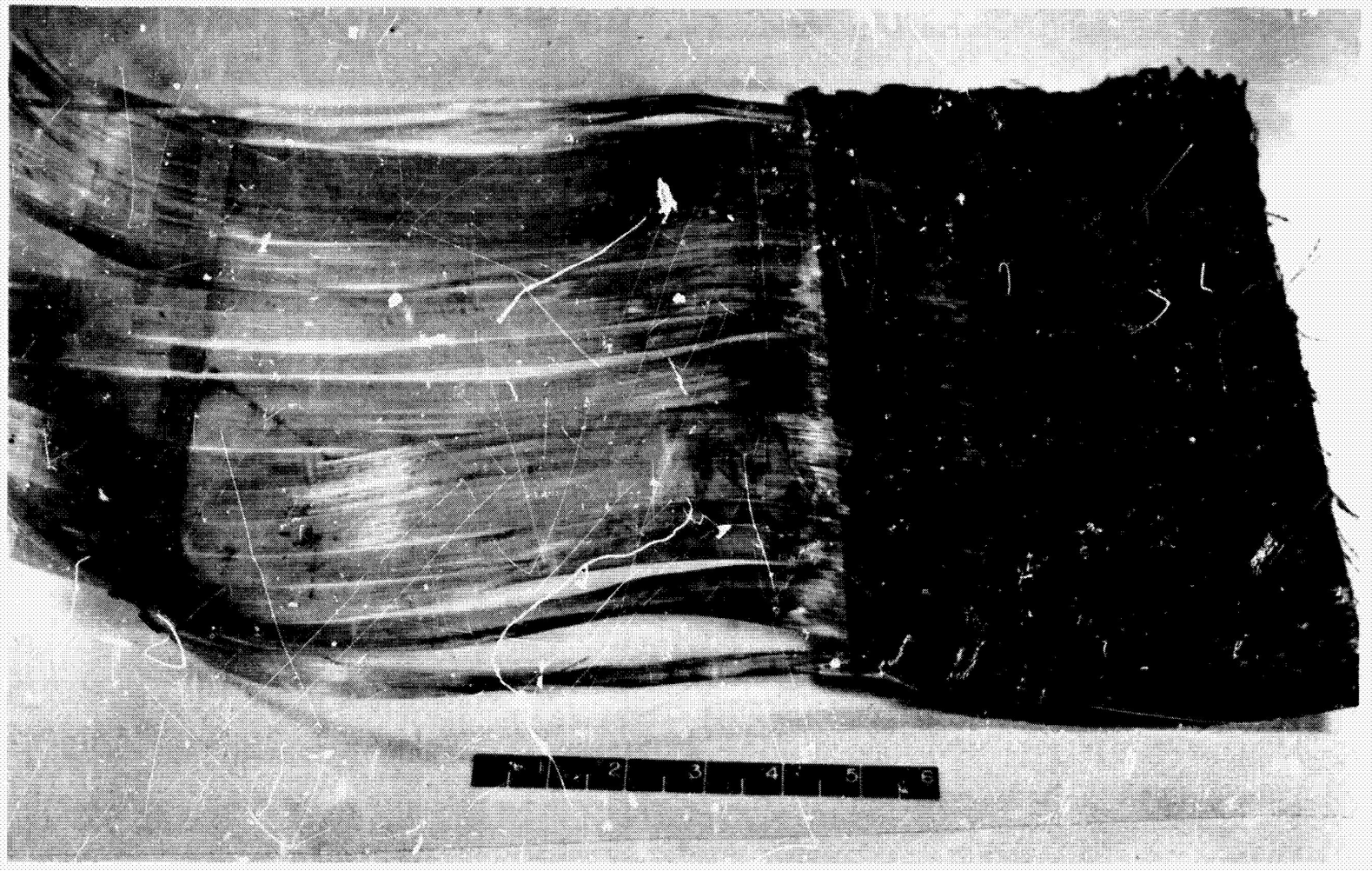


G-2184

FIGURE 38 - POST-FIRING PICTURE OF Y-195 (A10)

G-2183

FIGURE 39 - TOP VIEW OF ONE-HALF OF THE PATCH REPAIR ON Y-195 (A10)



G-2201

FIGURE 40 - UNDERSIDE VIEW OF ONE-HALF OF THE REPAIR PATCH ON Y-195 (A10)

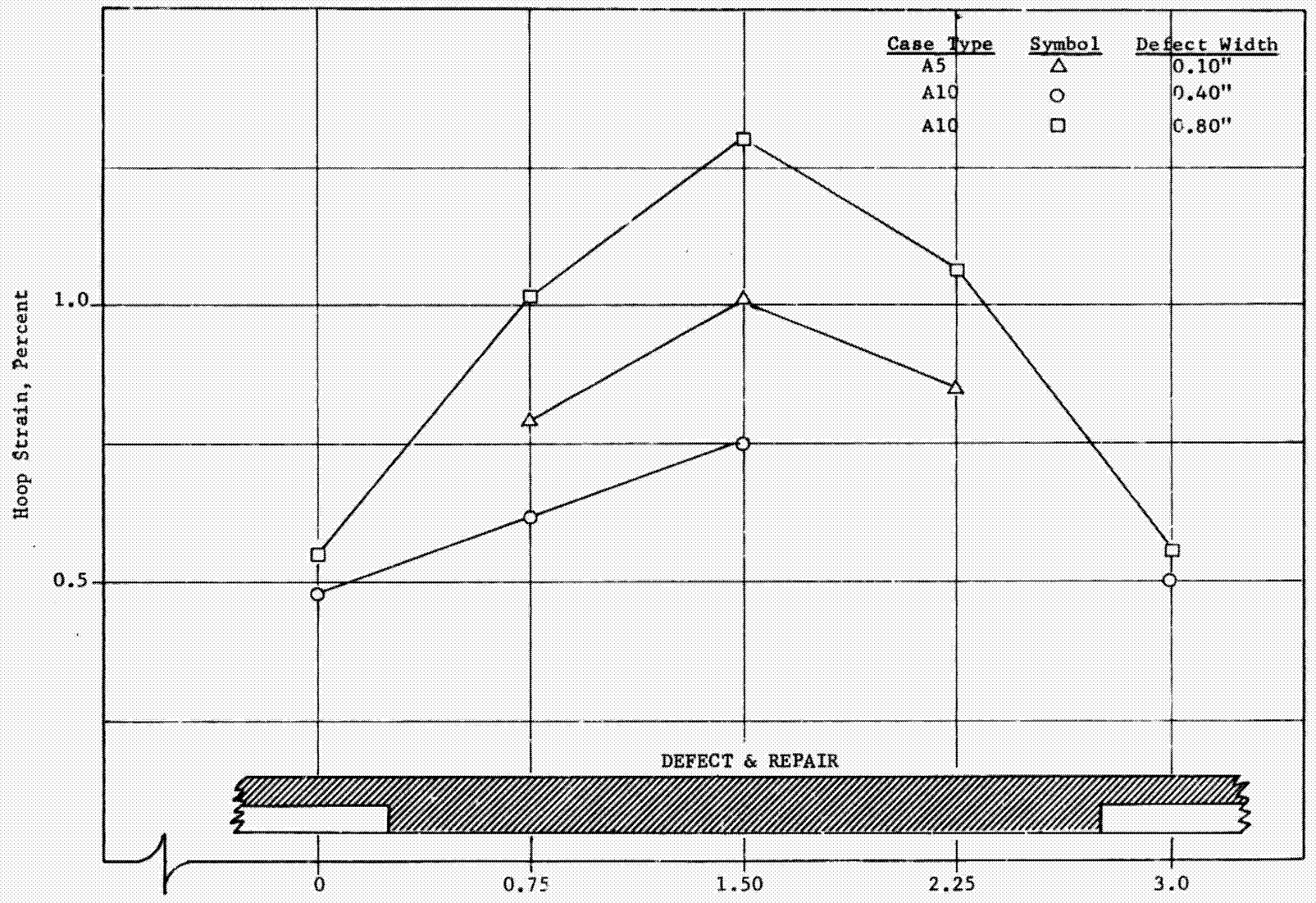


FIGURE 41 - COMPARISON OF WIDTHS FOR 2.50" LONG DEFECTS

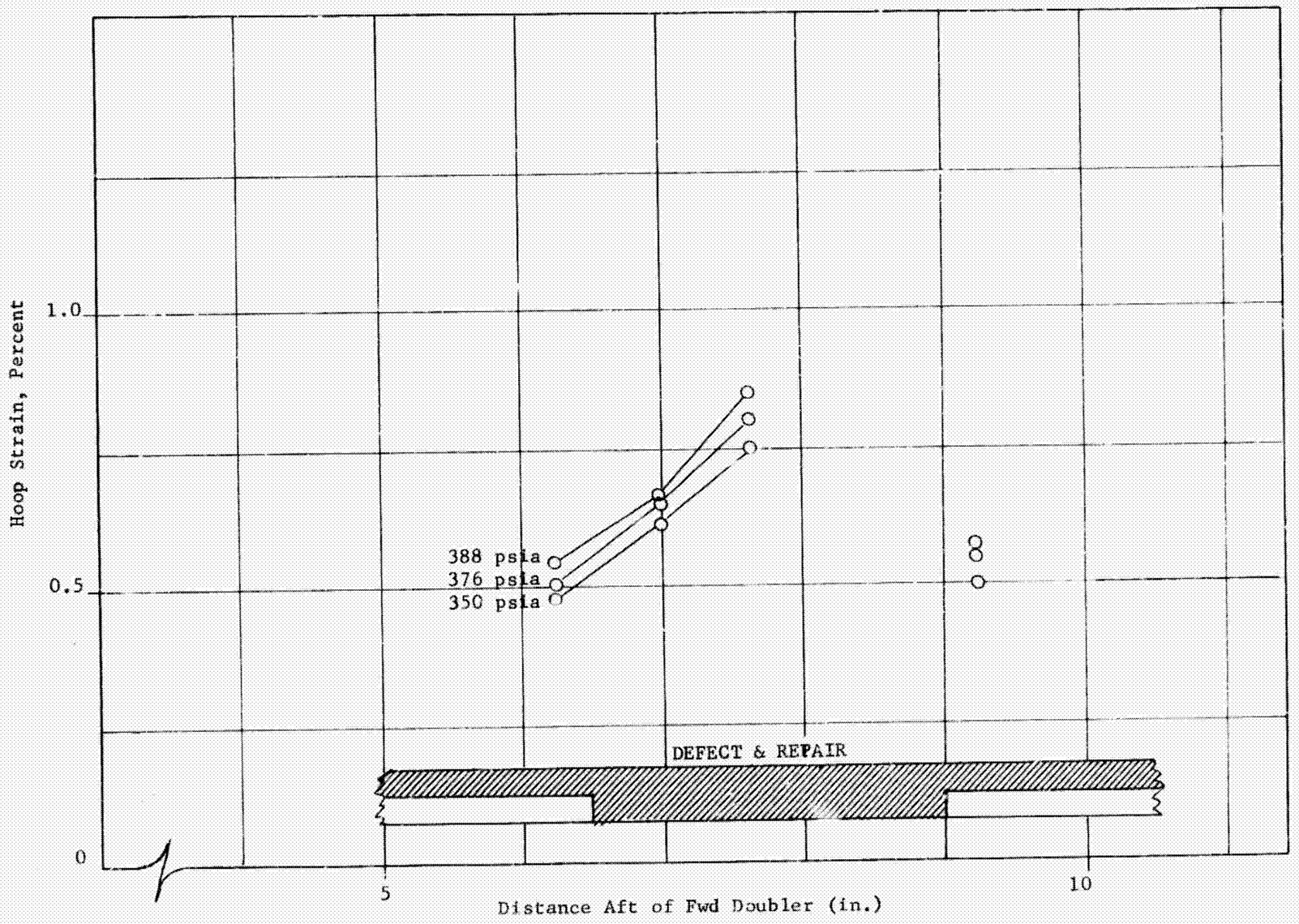


FIGURE 42 - HOOP STRAIN VS. PRESSURE FOR 2.50" LONG x 0.40" WIDE DEFECT ON Y-195 (A10)

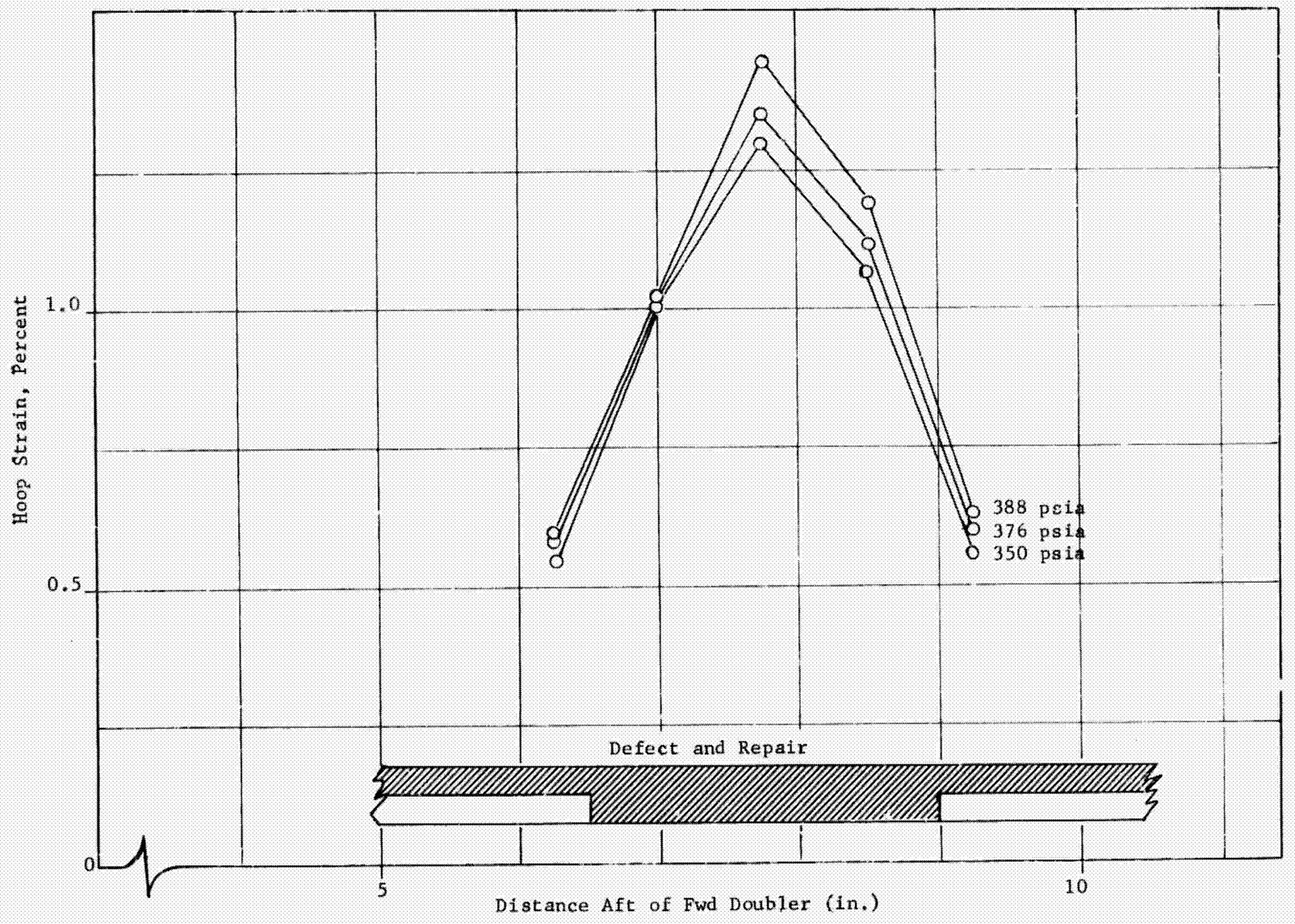


FIGURE 43 - HOOP STRAIN VS. PRESSURE FOR 2.50" LONG x 0.80" WIDE DEFECT ON Y-195 (A10)

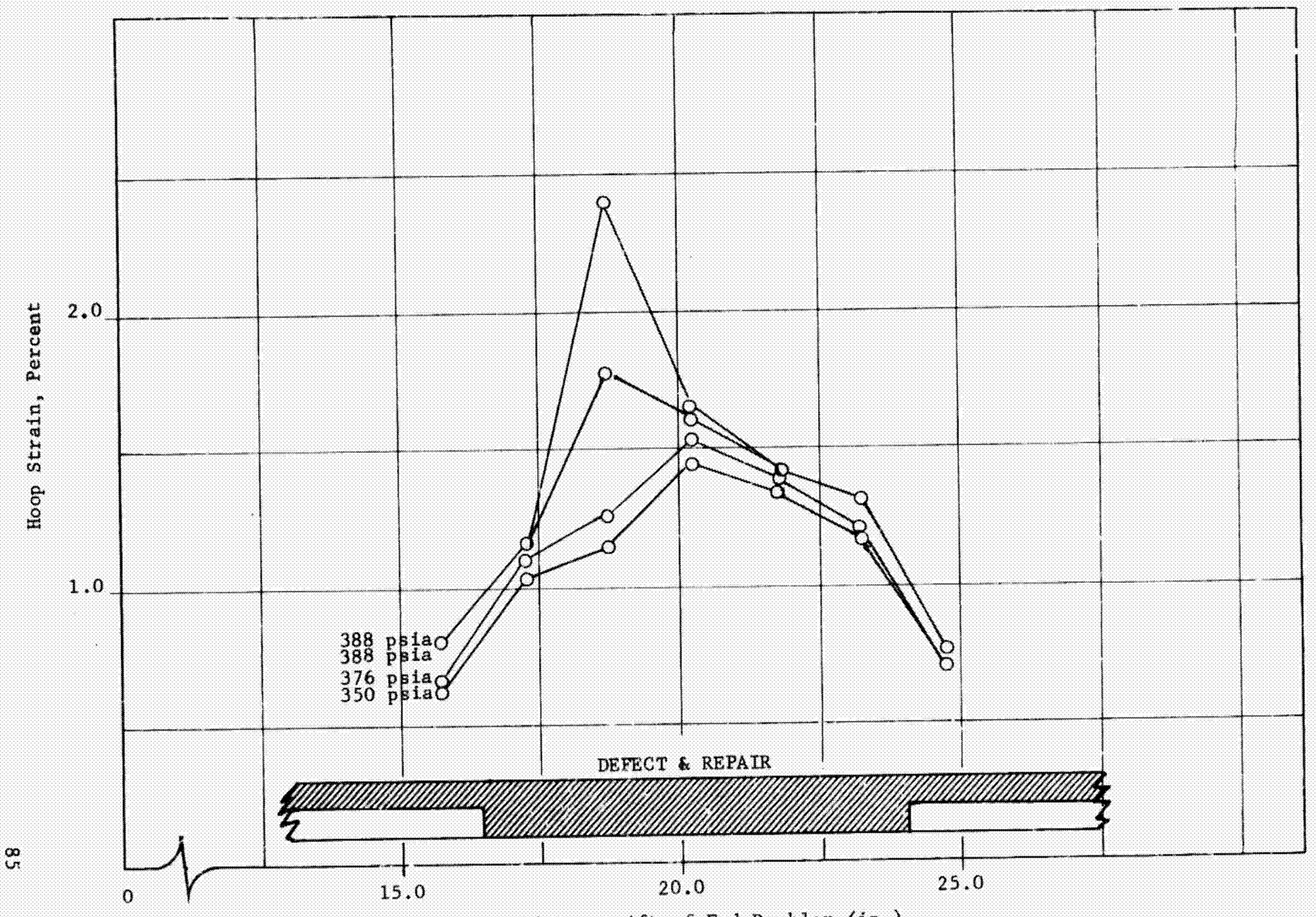


FIGURE 44 - HOOP STRAIN VS. PRESSURE FOR 7.50" LONG x 0.20" WIDE DEFECT ON Y-195 (A10)

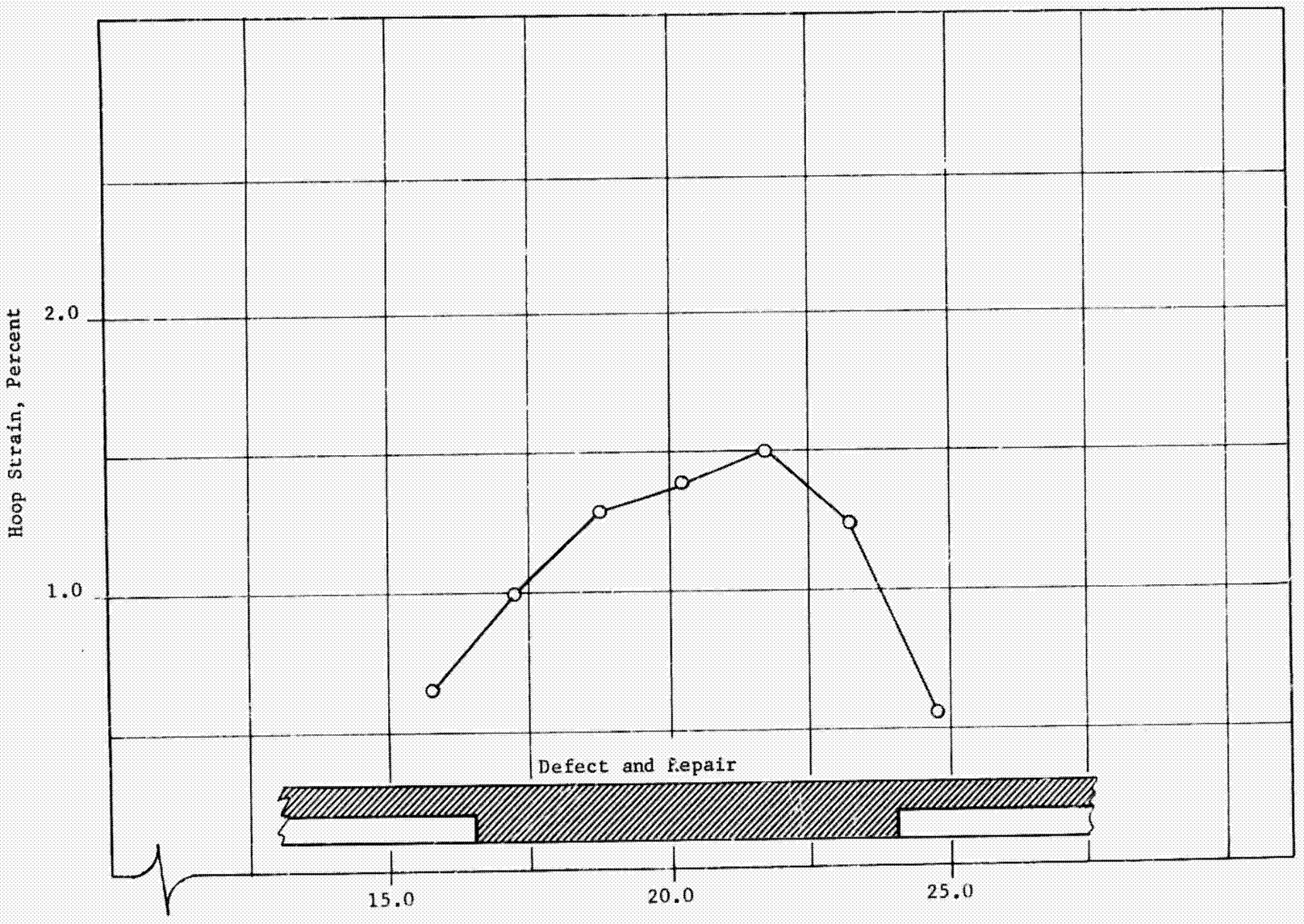


FIGURE 45 - HOOP STRAIN AT 388 PSIA FOR 7.50" LONC x 0.40" WIDE DEFECT ON Y-195 (A10)

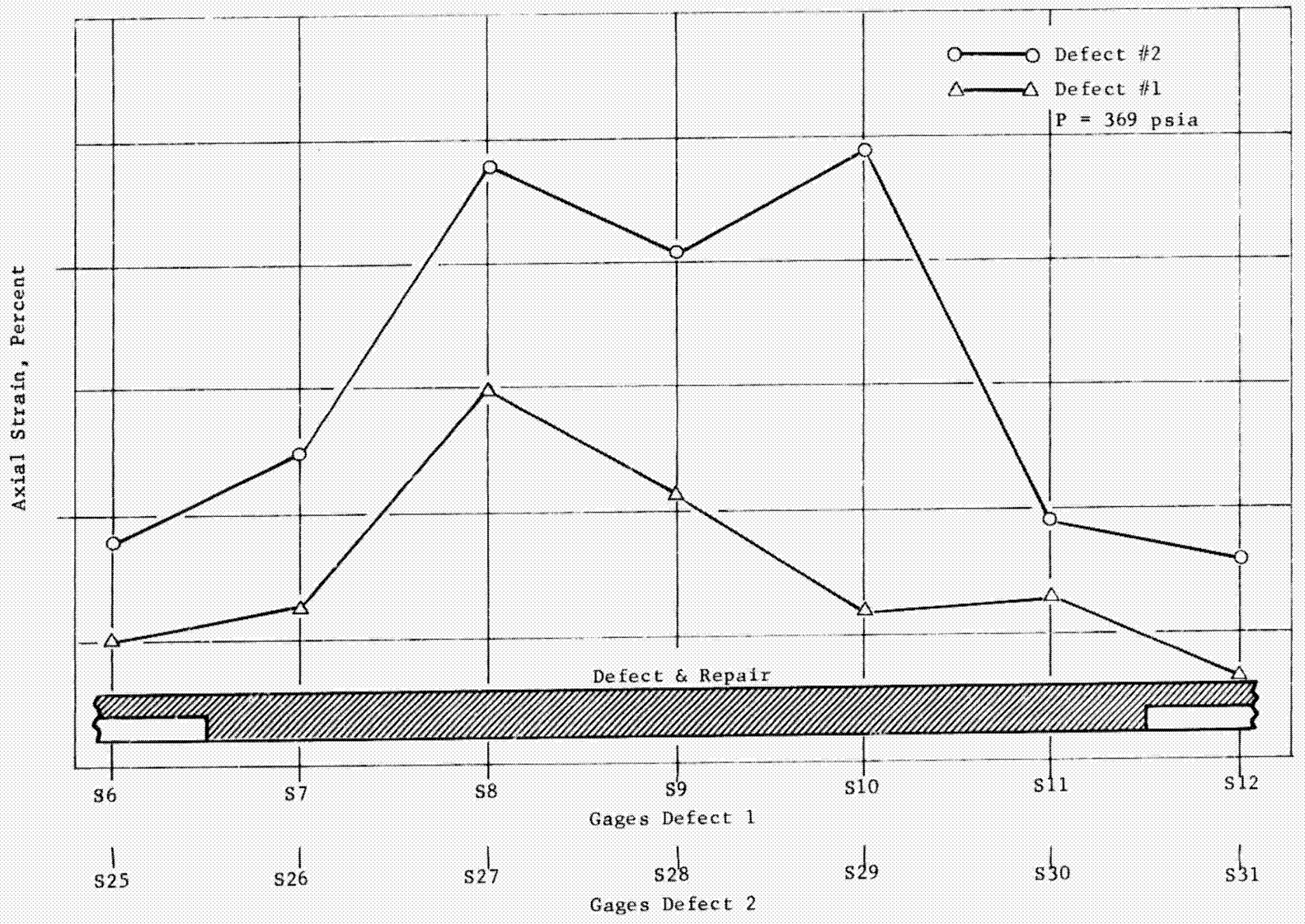


FIGURE 46 - AXIAL STRAINS VS. PRESSURE 7.5 IN. CIRCUMFERENTIAL DEFECTS X248 S/N NPP-445 (A6)

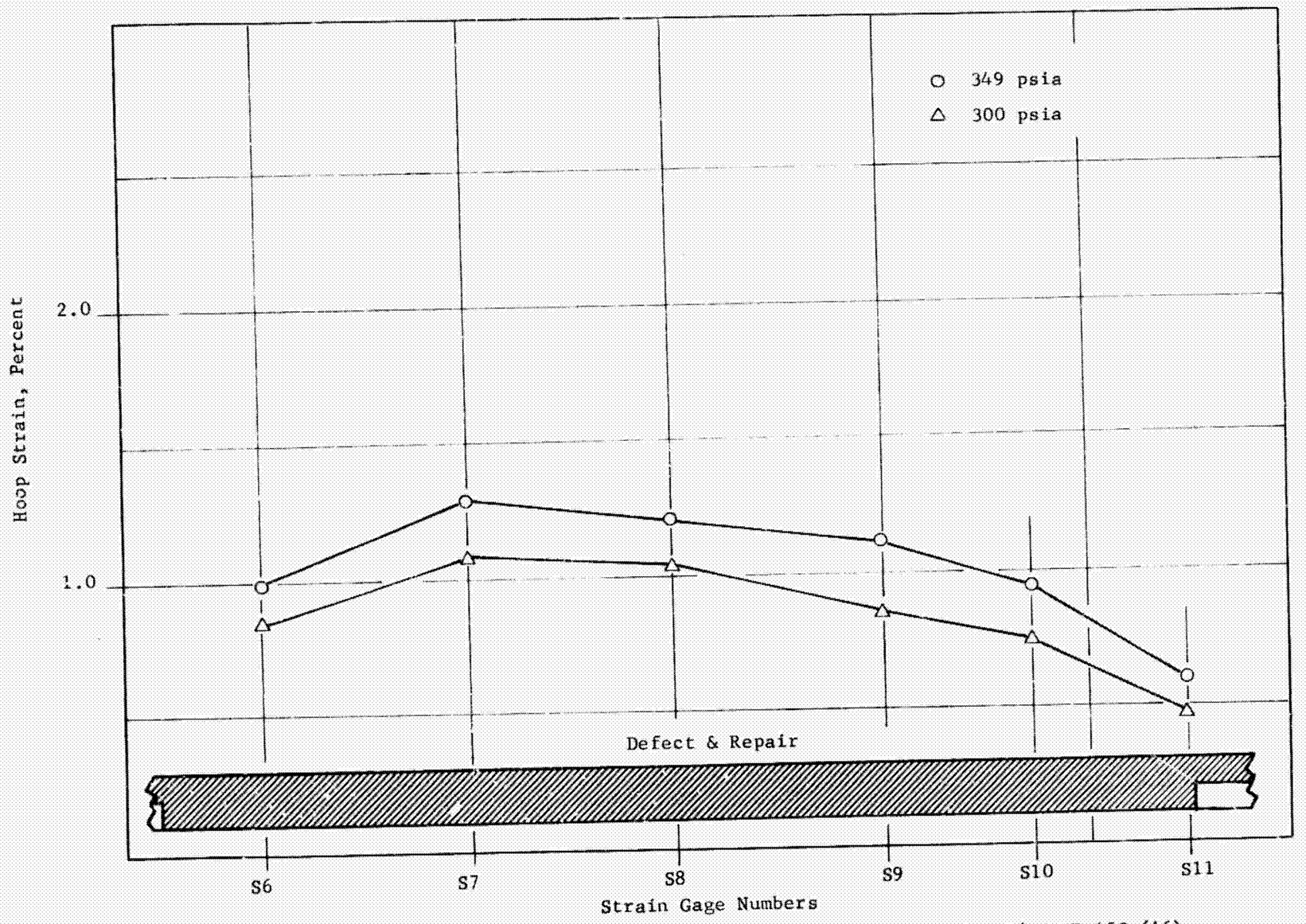


FIGURE 47 - HOOP STRAIN VS. PRESSURE 7.5 IN. LONGITUDINAL LEG X248 S/N NPP-453 (A6)

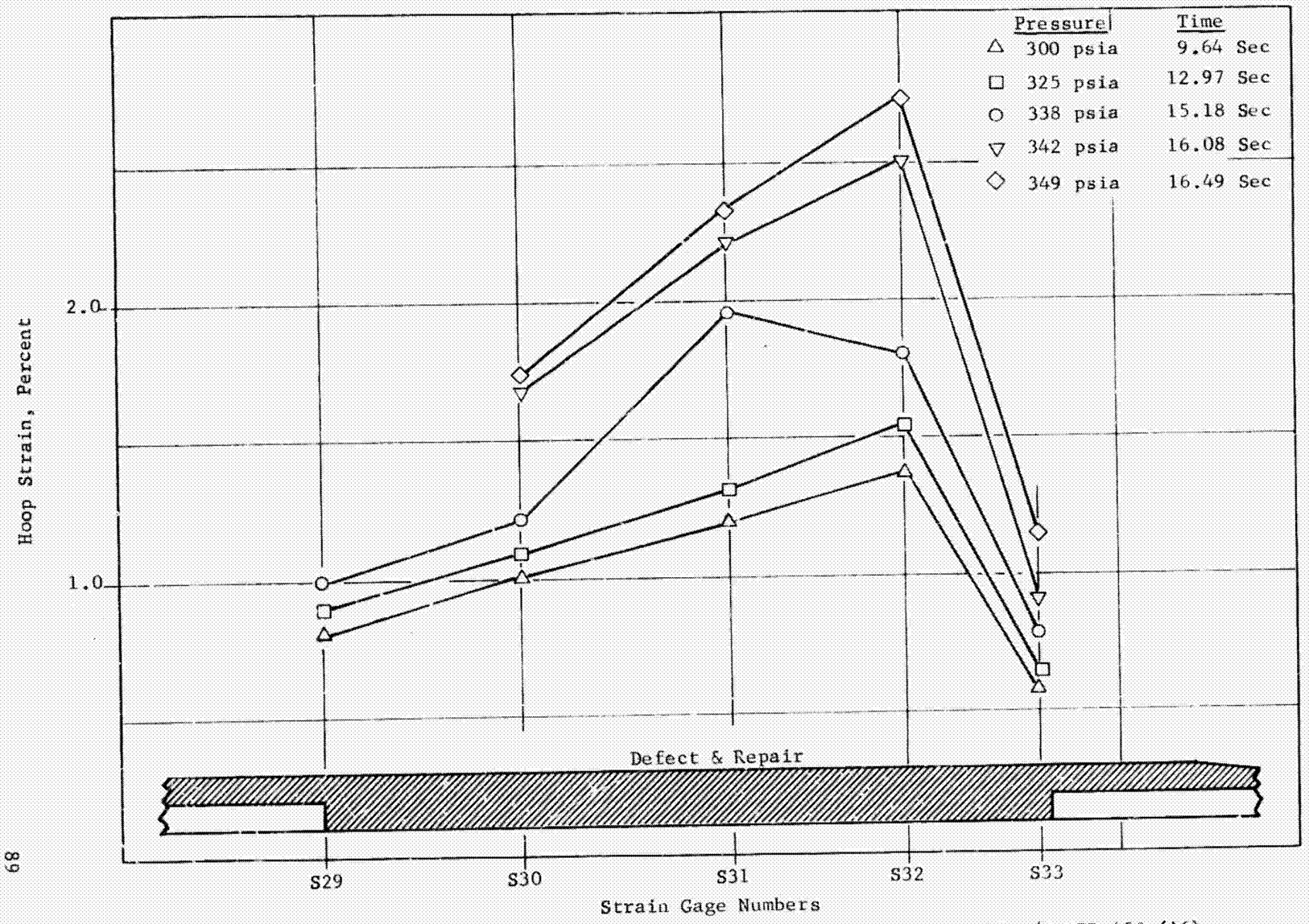


FIGURE 48 - HOOP STRAIN VS. PRESSURE 5.3 IN. LONGITUDINAL LEG X248 S/N NPP-453 (A6)

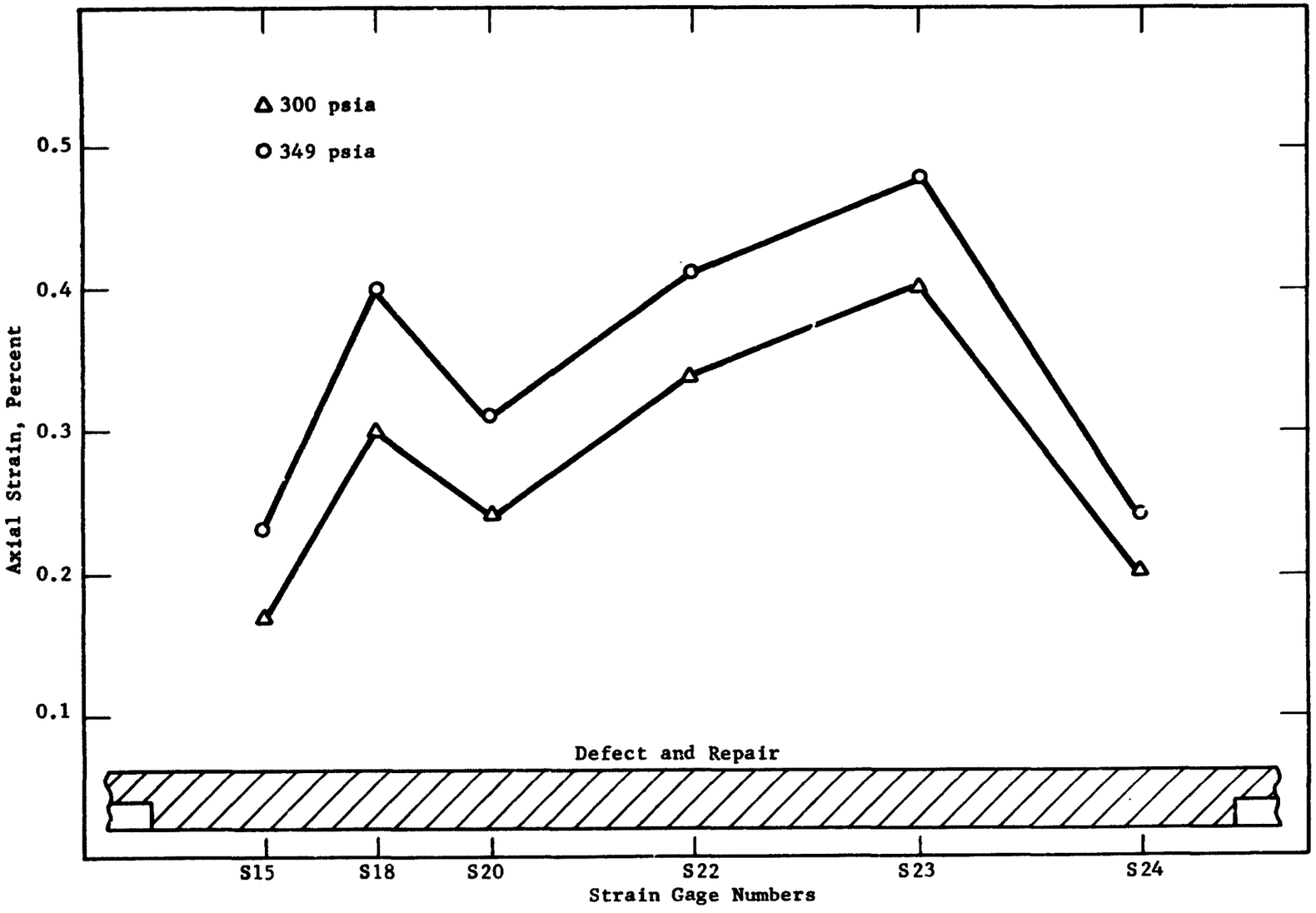


FIGURE 49 - AXIAL STRAIN VS. PRESSURE, 7.5-IN. CIRCUMFERENTIAL LEG - S/N NPP-453 (A6)

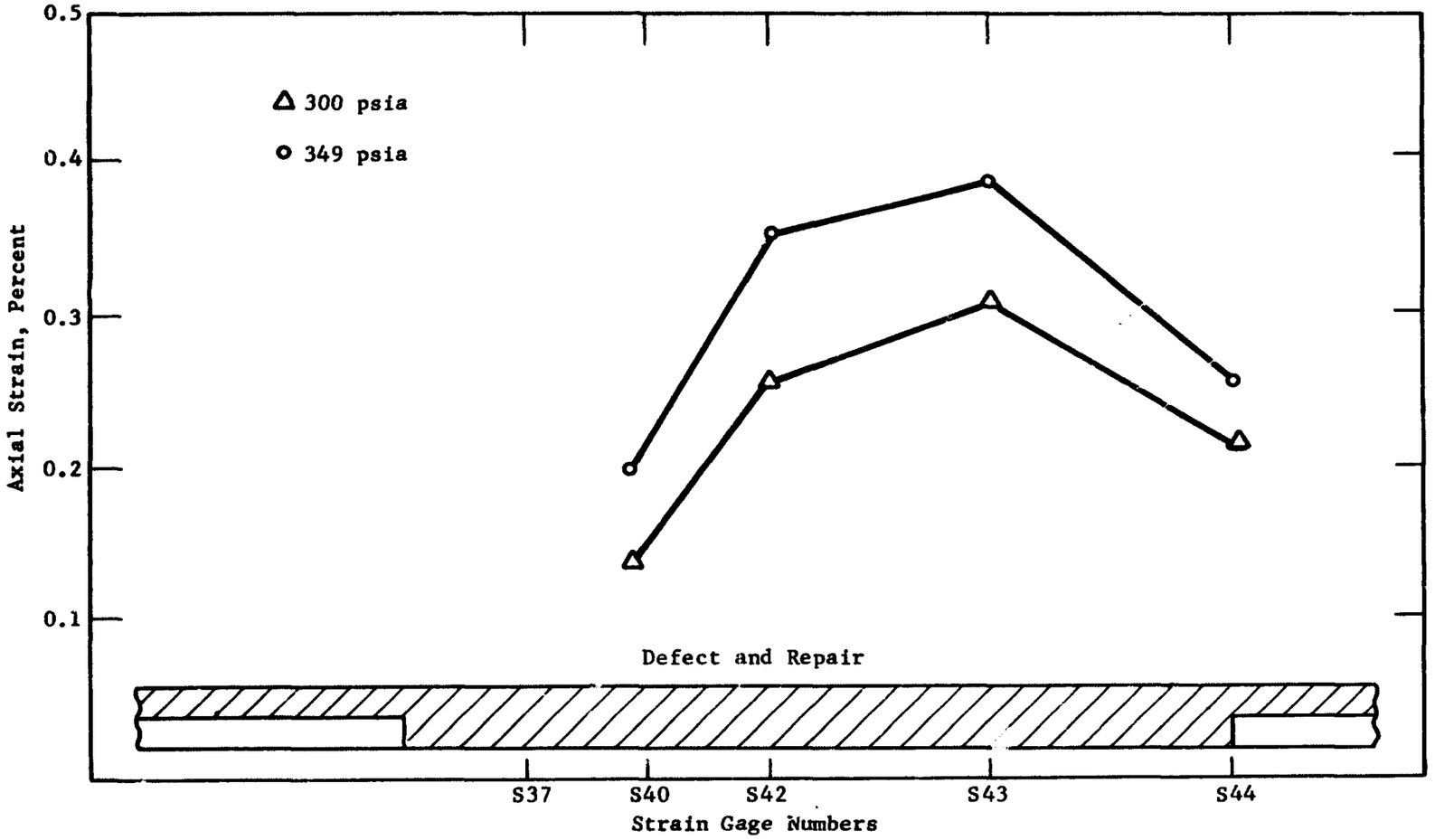


FIGURE 50 - AXIAL STRAIN VS. PRESSURE, 5.3-IN. CIRCUMFERENTIAL LEG - S/N NPP-453 (A6)

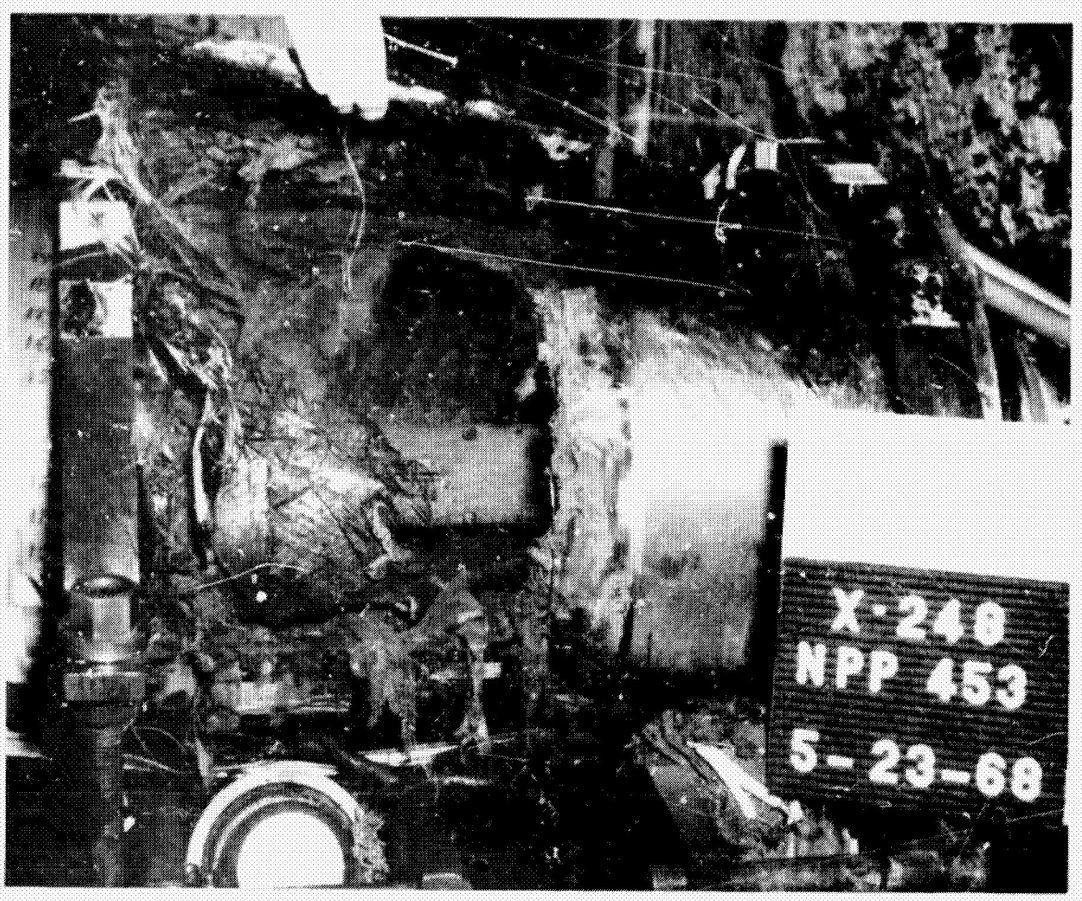


FIGURE 51 - FAILURE OF S/N NPP-453 (A6) CHAMBER

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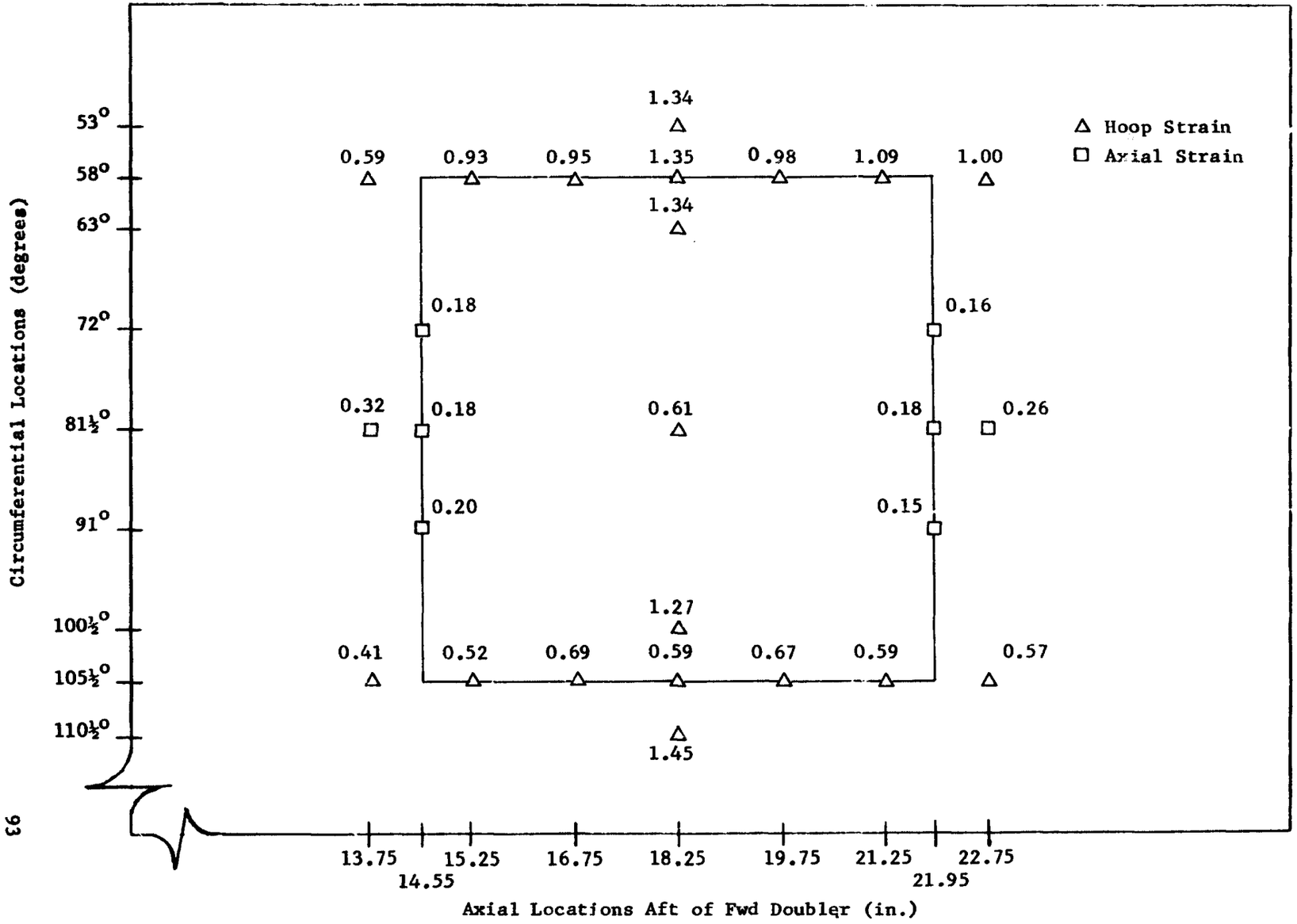


FIGURE 52 - STRAIN READINGS FOR 7.5 IN. SQUARE DEFECT AT 388 PSIA ON NPP-463 (A6)

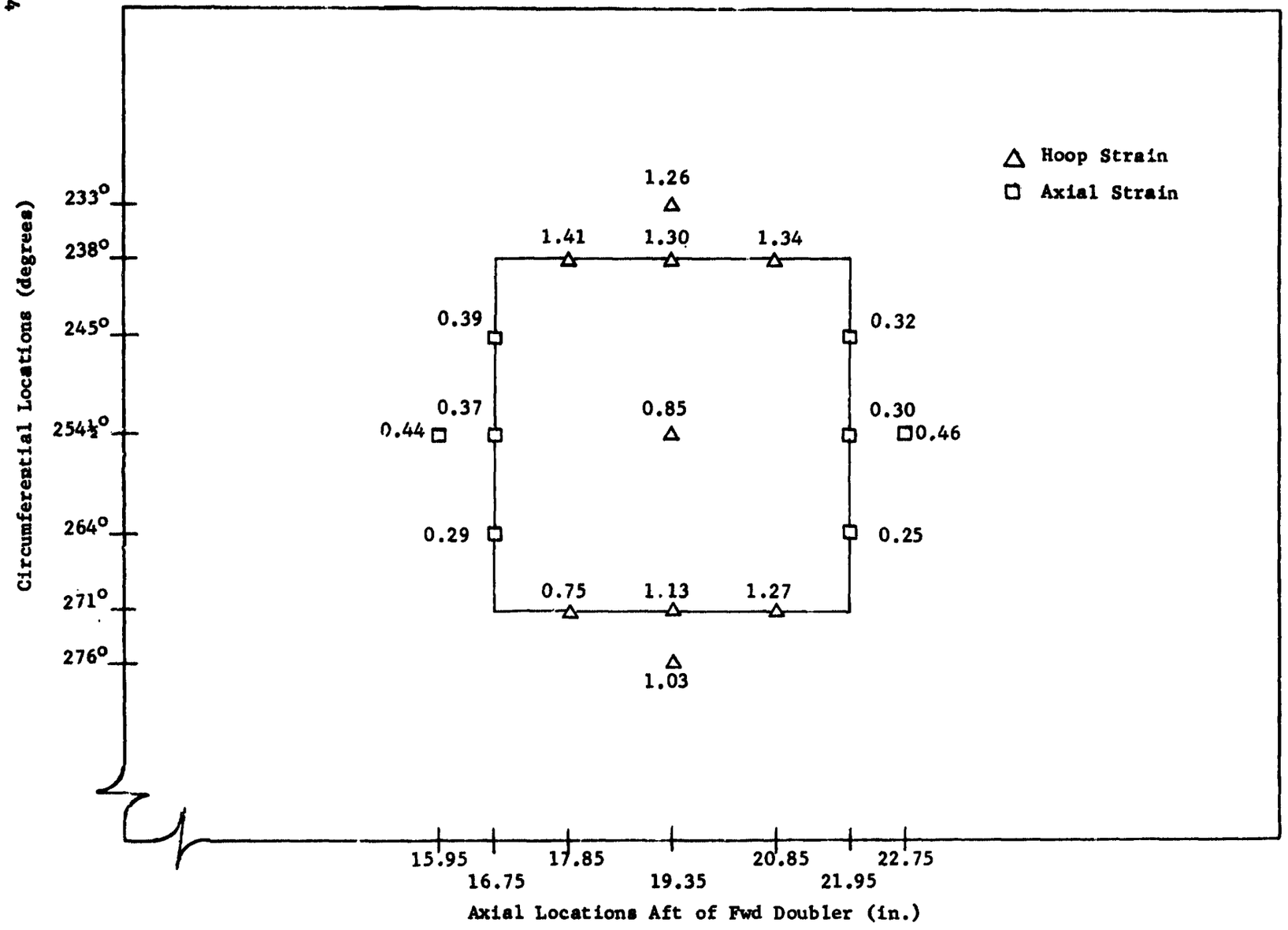


FIGURE 53 - STRAIN READINGS FOR 5.3 IN. SQUARE DEFECT AT 388 PSIA ON NPP-463 (A6)

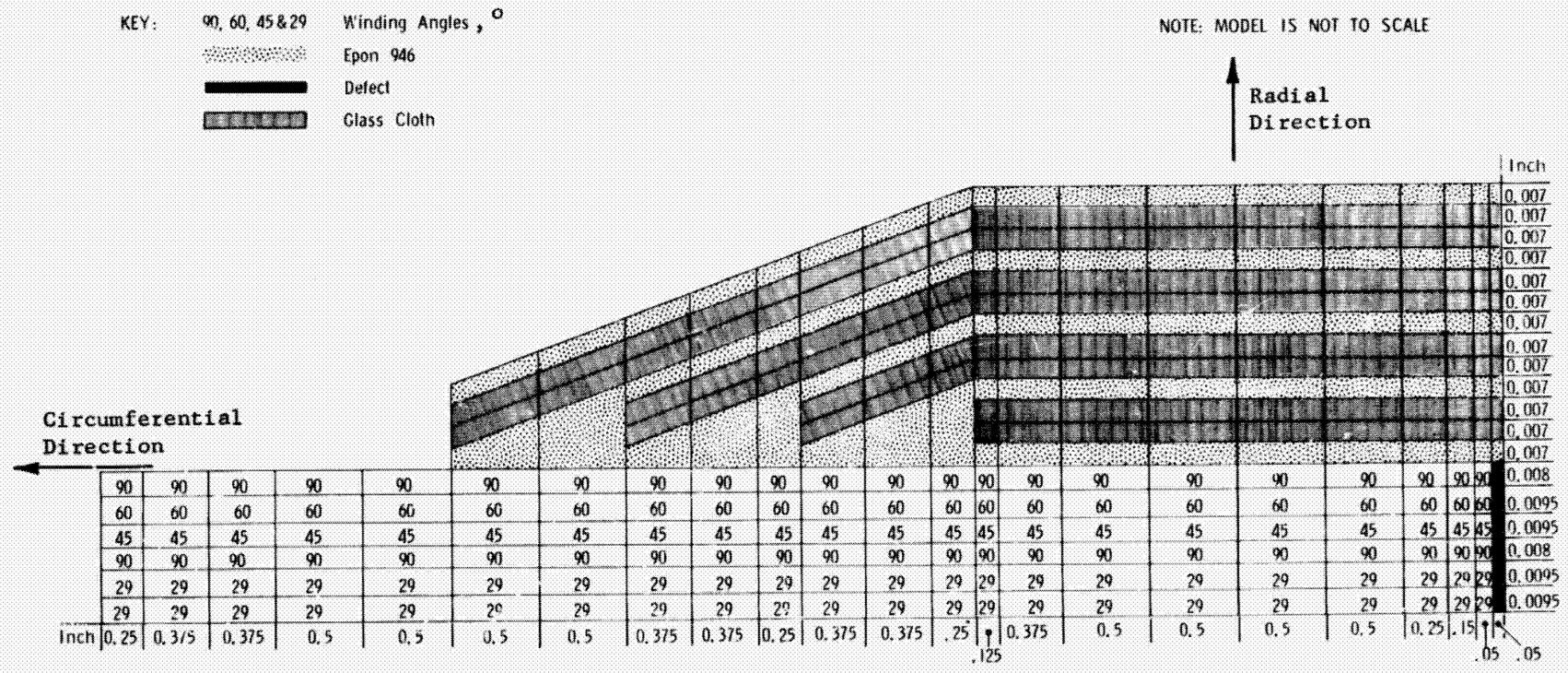


FIGURE 54 - Mathematical Model of Cylindrical Section Repair

Adhesive	.04	.04	.05	.08	.11	.12	.14
Glass	.78	.79	.91	1.43	2.04	2.25	2.41
Cloth	.78	.79	.91	1.42	2.04	2.34	2.38
Bond Layer	.04	.04	.05	.10	.13	.14	.15
Glass	.78	.79	.89	1.36	2.08	2.47	2.6
Cloth	.78	.79	.89	1.35	2.09	2.58	2.66
Bond Layer	.04	.04	.06	.15	.22	.21	.19
Glass	.78	.79	.86	1.22	2.09	2.95	3.28
Cloth	.78	.79	.85	1.17	2.07	3.12	3.49
Bond Layer	.04	.04	.06	.20	.39	.43	.31
Glass	.78	.78	.81	.98	1.78	3.77	5.32
Cloth	.78	.78	.80	.93	1.67	3.75	6.3
Bond Layer	.04	.04	.06	.22	.67	1.37	1.04
Fiberglass	8.32	8.31	8.13	7.34	5.90	4.59	
Chamber	3.78	3.78	3.70	3.32	2.59	1.69	
	1.88	1.88	1.84	1.66	1.40	1.22	
	8.32	8.30	8.12	7.28	5.54	3.18	
	1.30	1.29	1.27	1.13	.85	.63	
	1.30	1.29	1.27	1.13	.85	.63	

FIGURE 55 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 1

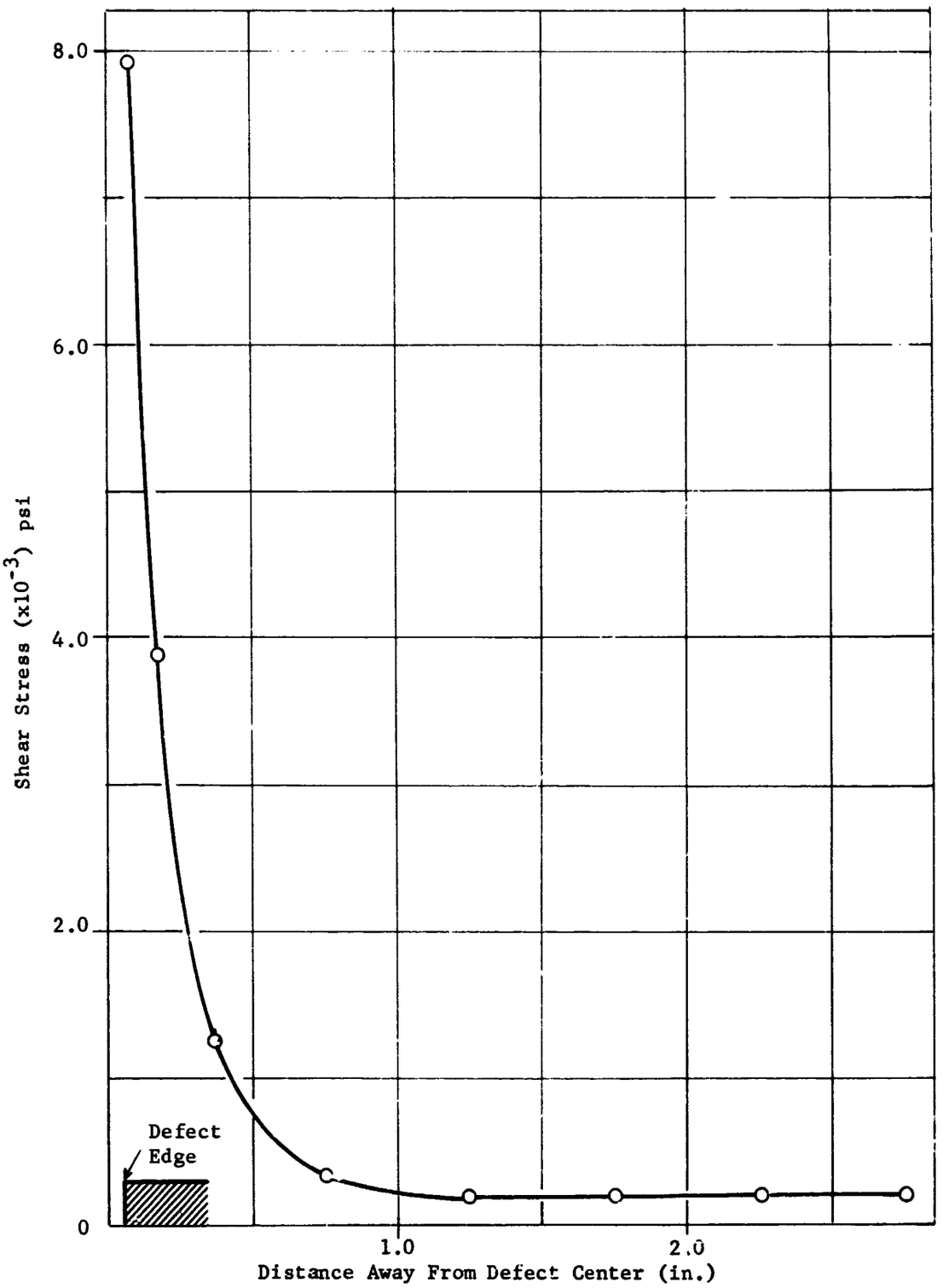


FIGURE 56 - SHEAR STRESS DISTRIBUTION ALONG BOND LINE

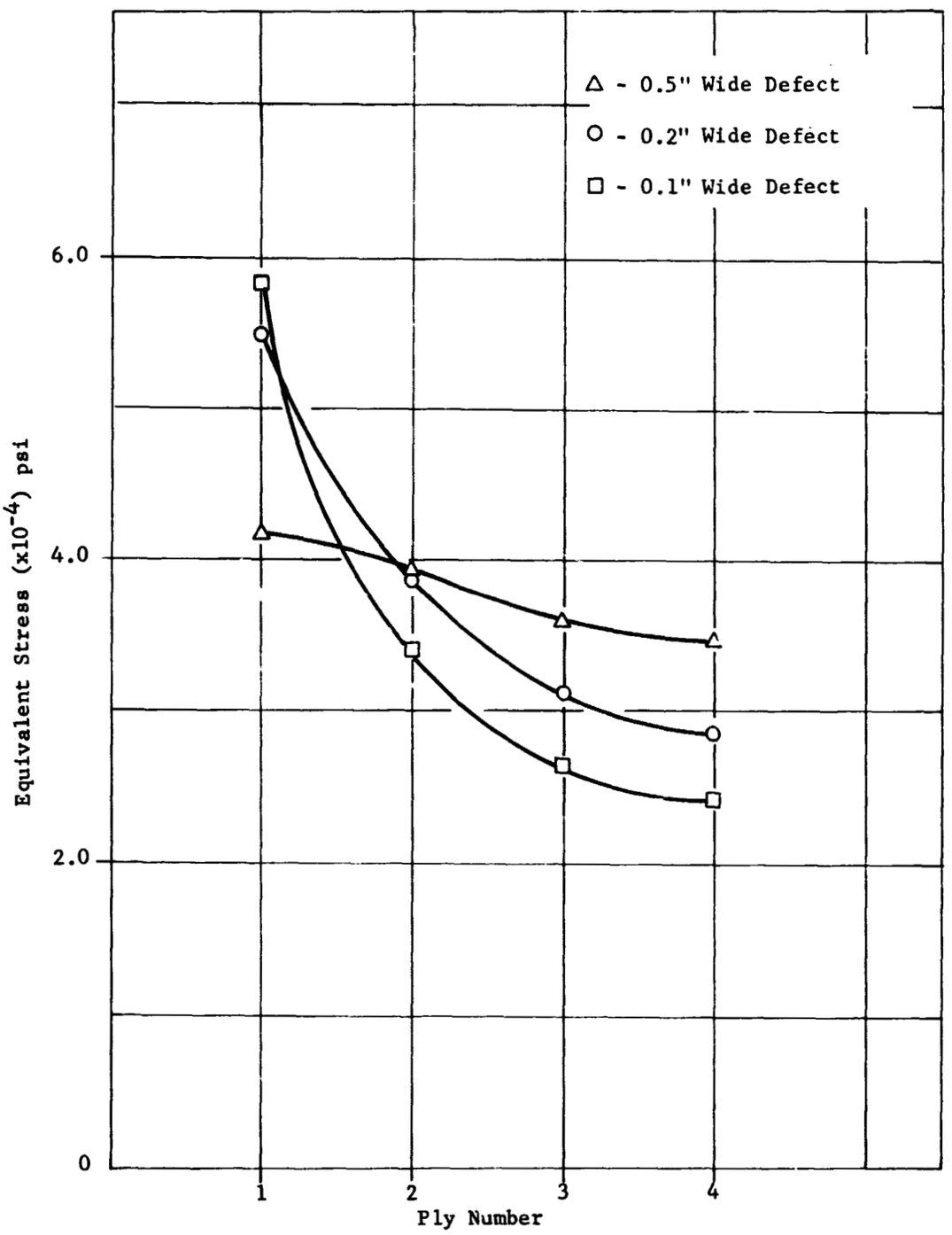


FIGURE 57 - COMPARISON OF AVERAGE EQUIVALENT STRESS LEVEL PER PLY VERSUS CHANGES IN DEFECT WIDTH (STRESS MEASURED AT DEFECT CENTER)

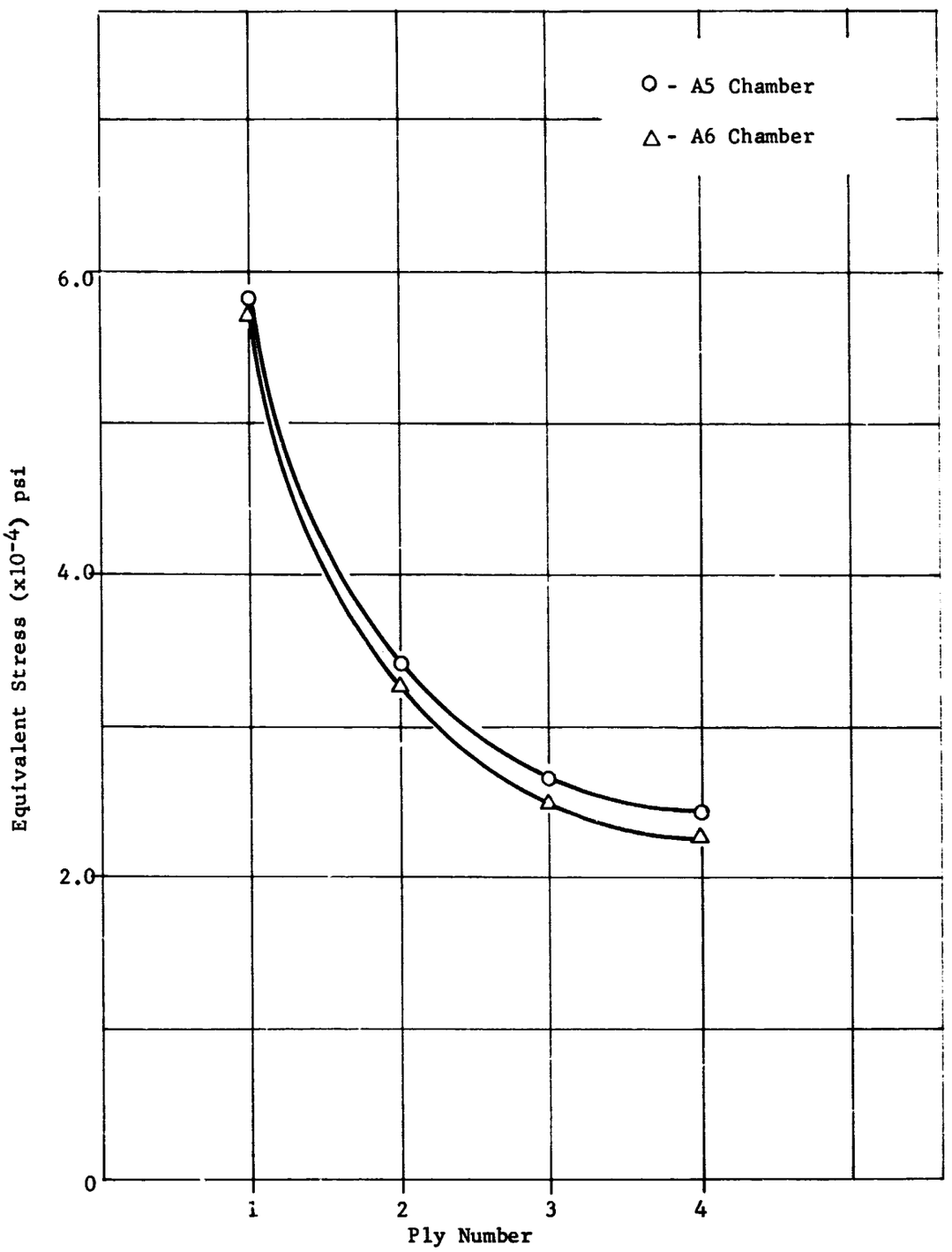


FIGURE 58 - COMPARISON OF STRESSES IN PATCH FOR A5 AND A6 CHAMBERS - CONDITION 5

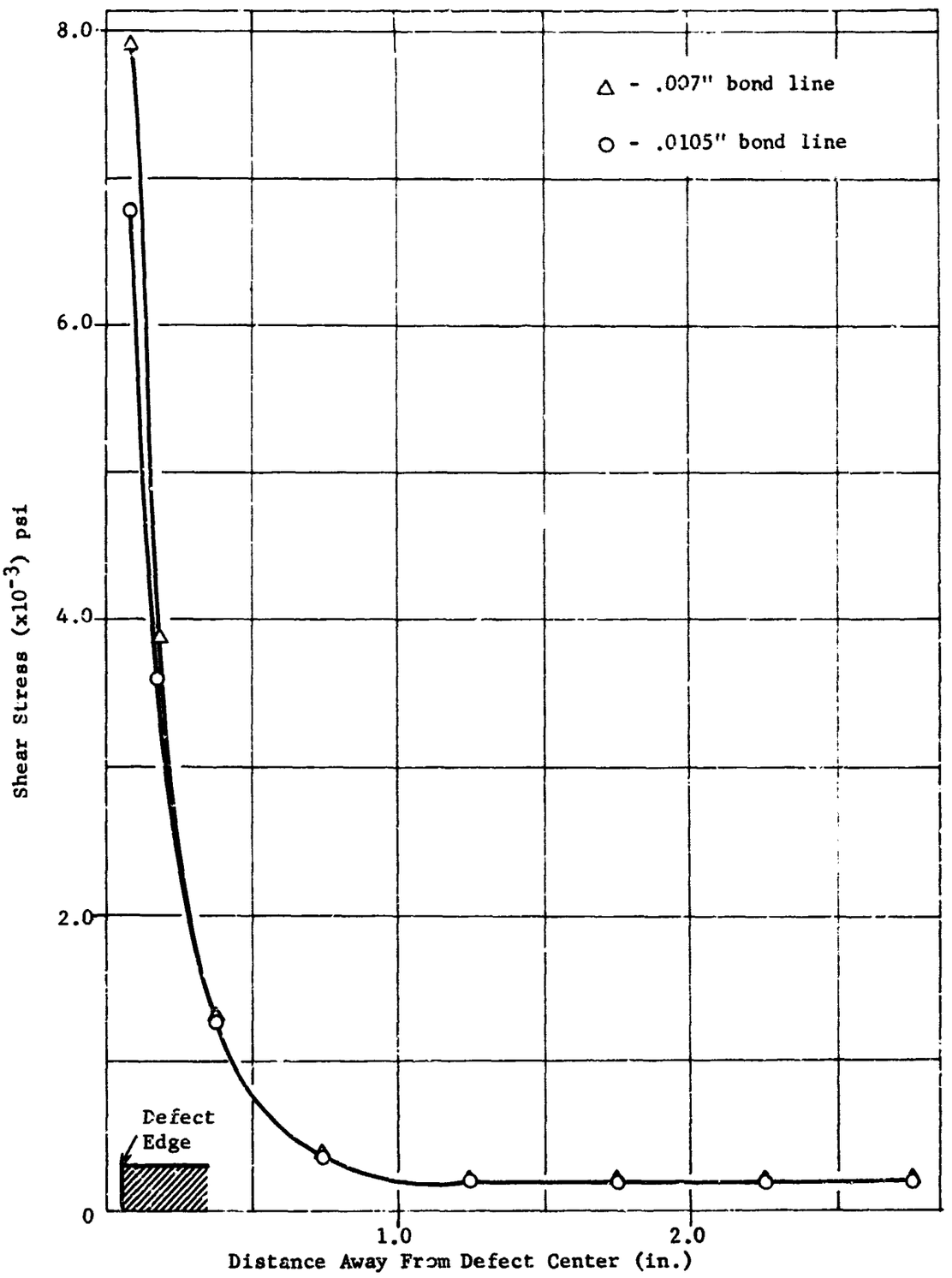


FIGURE 59 - COMPARISON OF SHEAR STRESSES FOR TWO BOND LINE THICKNESSES

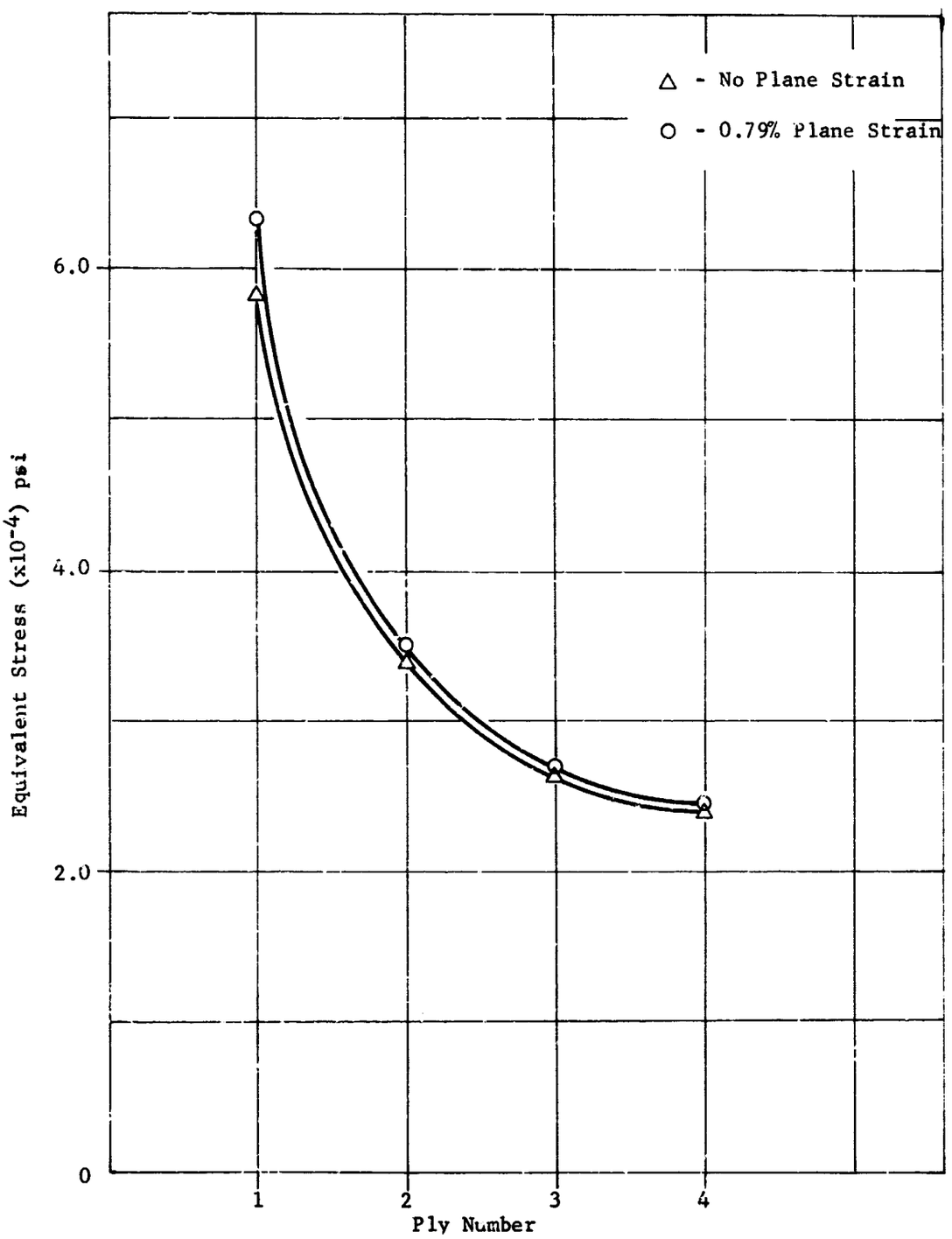


FIGURE 60 - COMPARISON OF CONDITIONS 1 AND 7

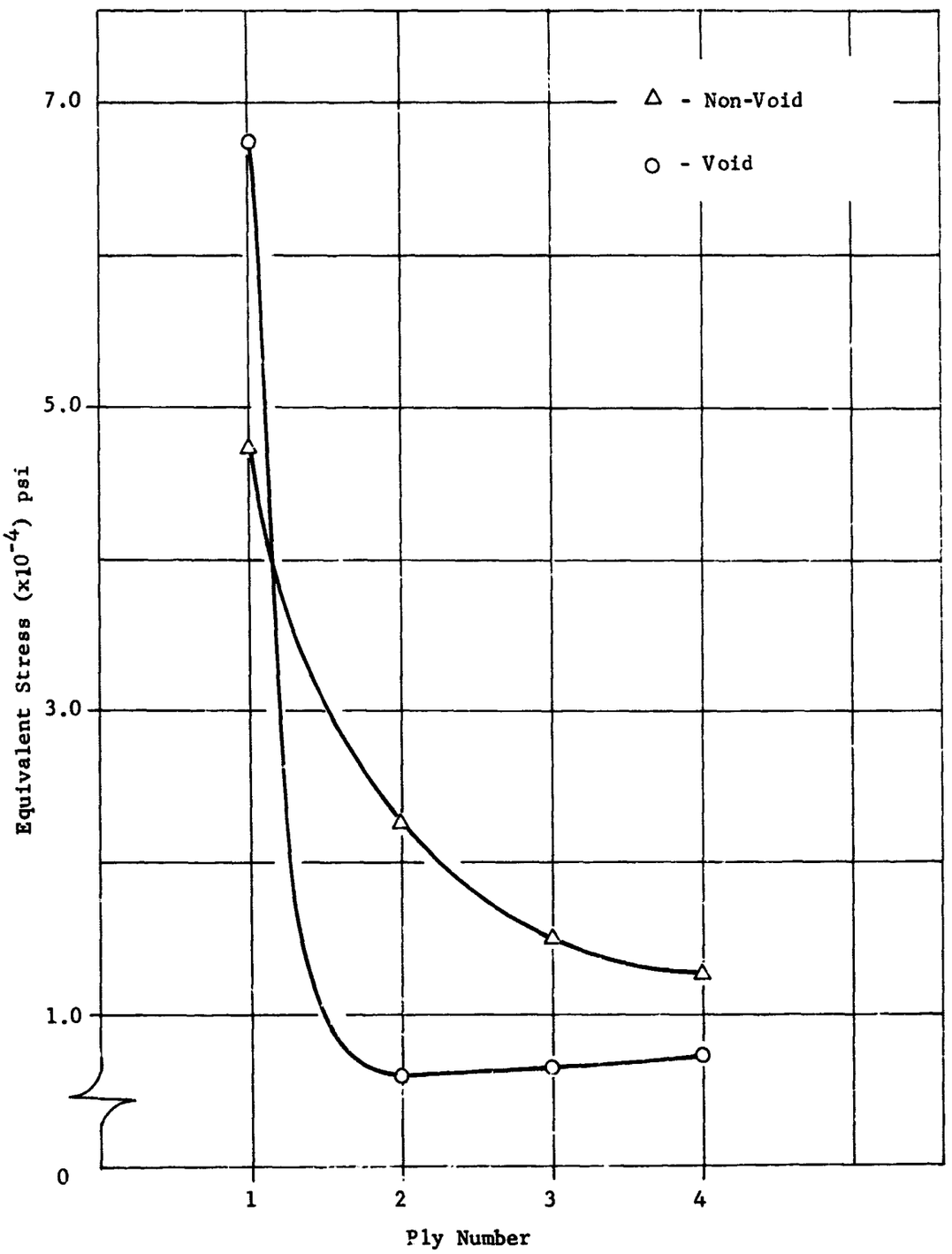


FIGURE 61 - COMPARISON OF STRESSES IN PATCHES WITH AND WITHOUT VOIDS

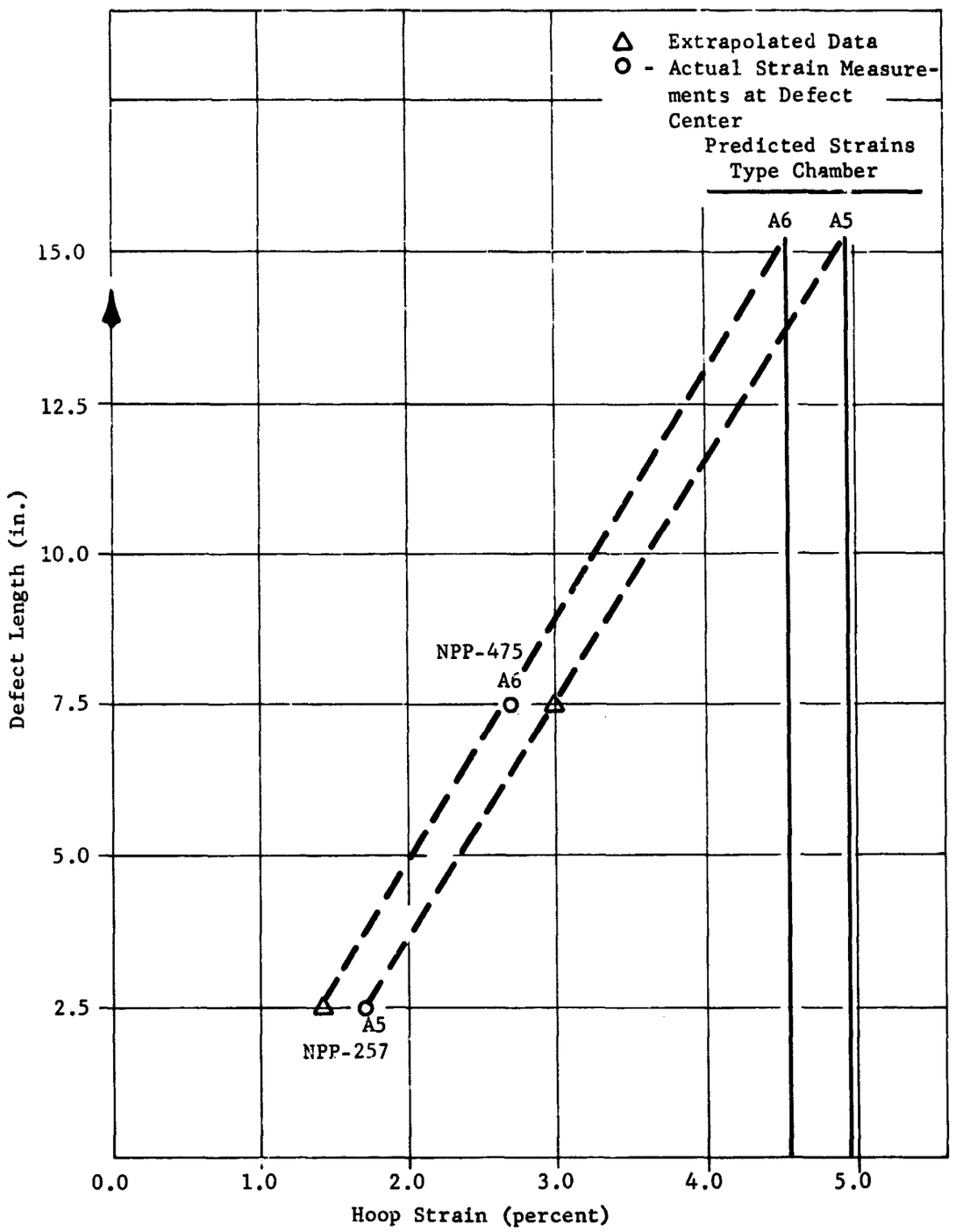


FIGURE 62 - COMPARISON OF PREDICTED AND ACTUAL STRAINS FOR A THREE PLY REPAIR OF A 0.1-INCH WIDE DEFECT AT 350 PSIA

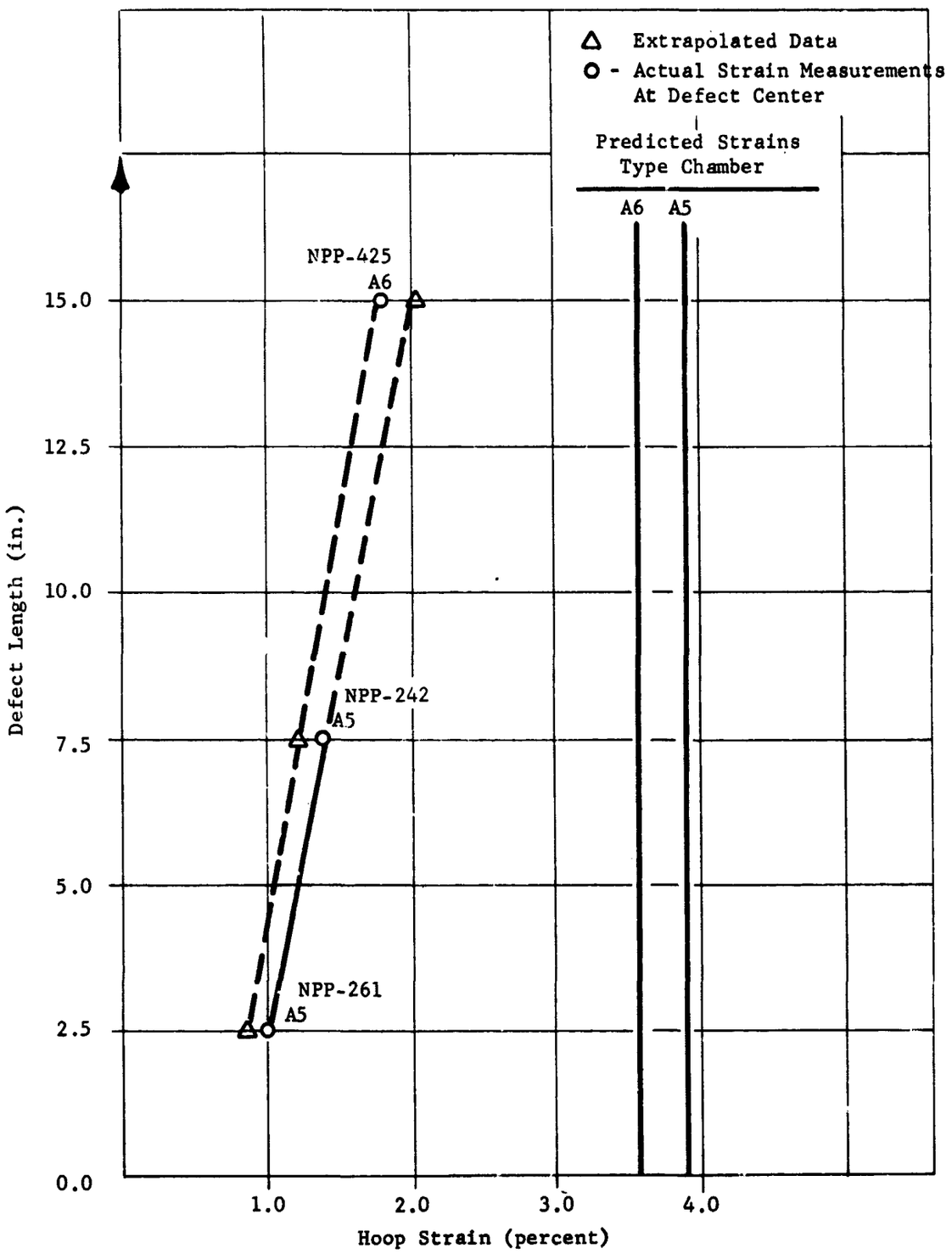
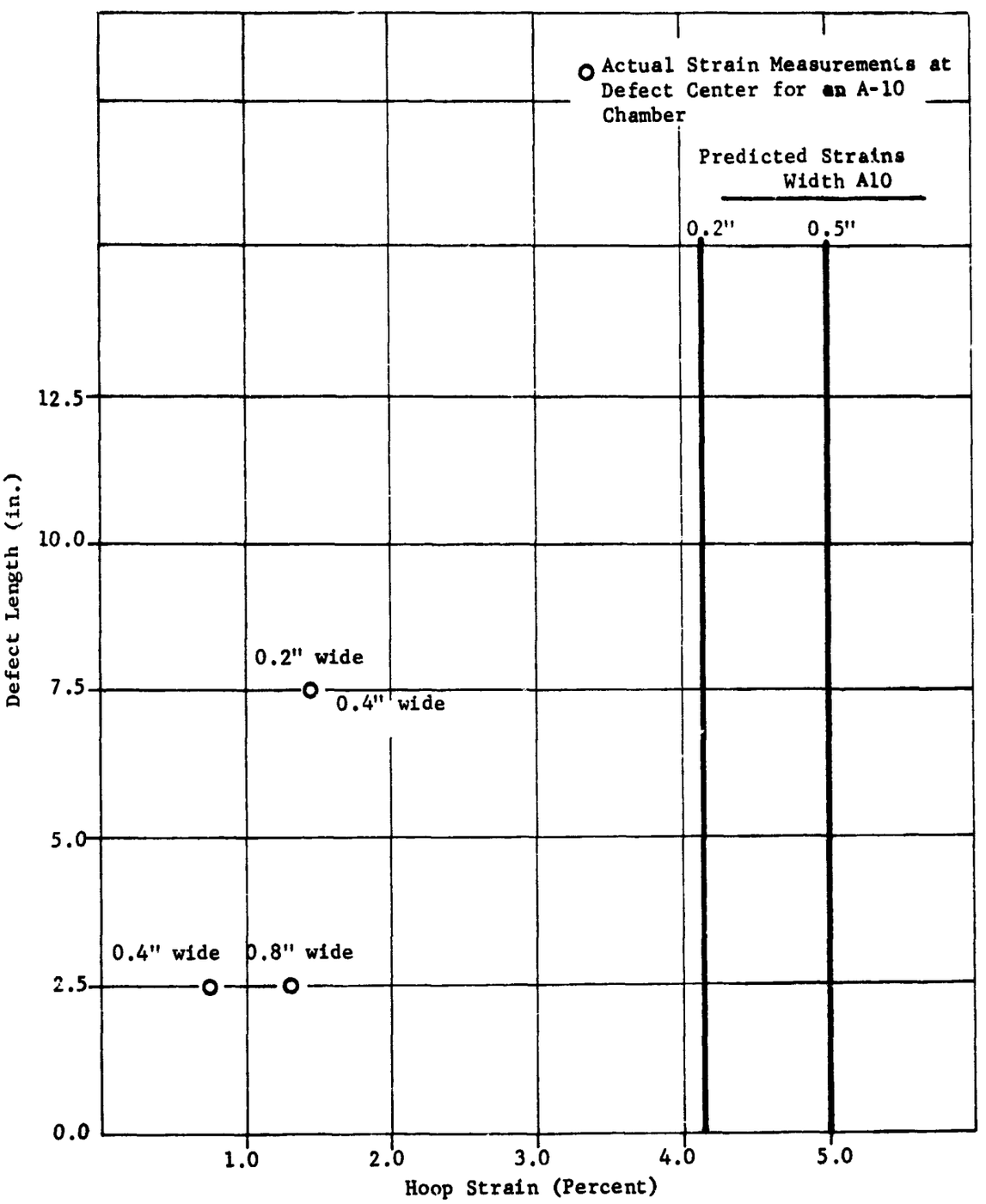


FIGURE 63 - COMPARISON OF PREDICTED AND ACTUAL STRAINS FOR A FOUR PLY REPAIR OF A 0.1-INCH WIDE DEFECT AT 350 PSIA



FIGUPE 64 - COMPARISON OF PREDICTED AND ACTUAL STRAINS FOR A FOUR PLY REPAIR OF VARIOUS SIZE DEFECTS

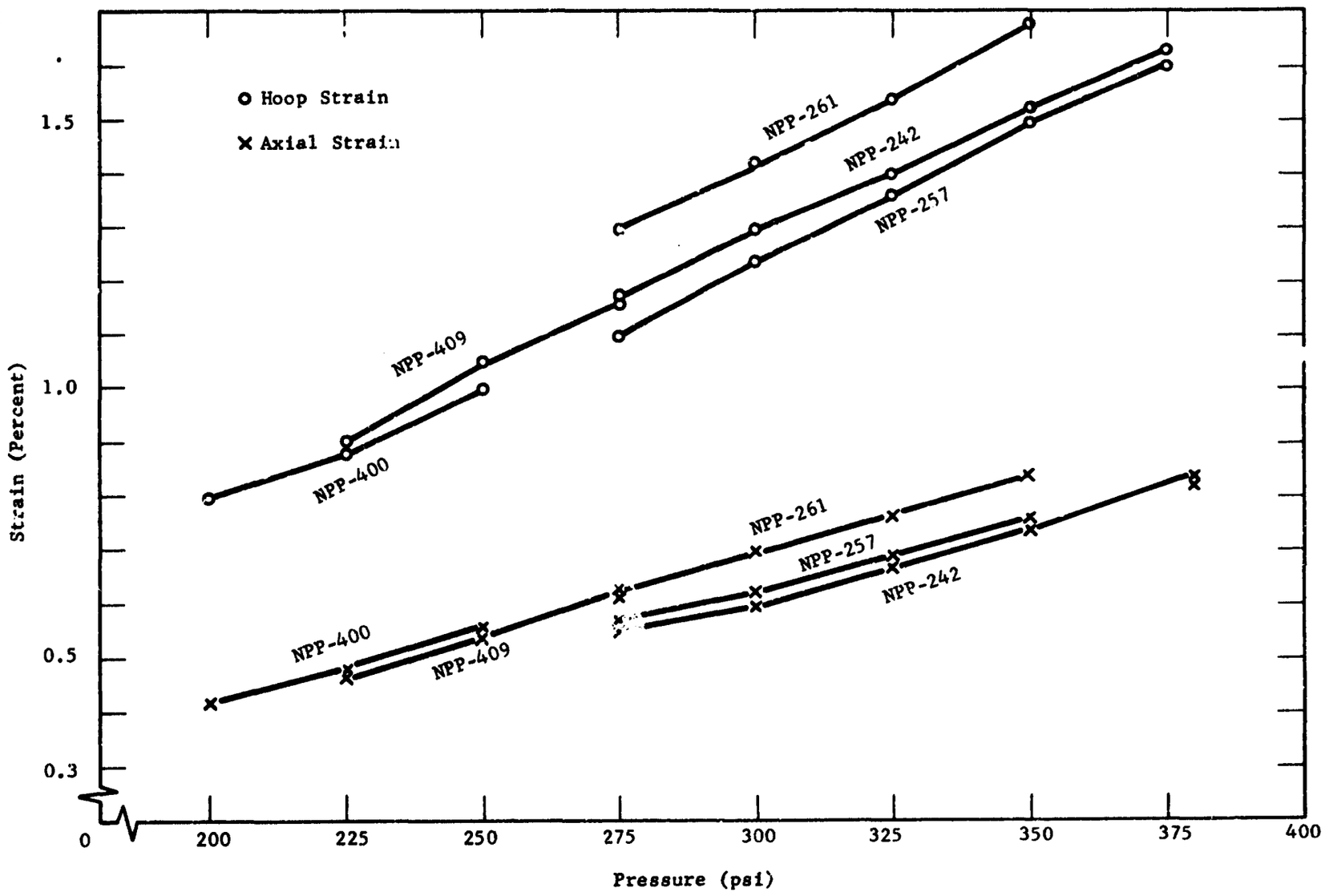


FIGURE 65 - HOOP AND AXIAL STRAIN VS. PRESSURE FOR X248A5 CHAMBERS IN AREAS REMOTE FROM DEFECTS AND REPAIRS

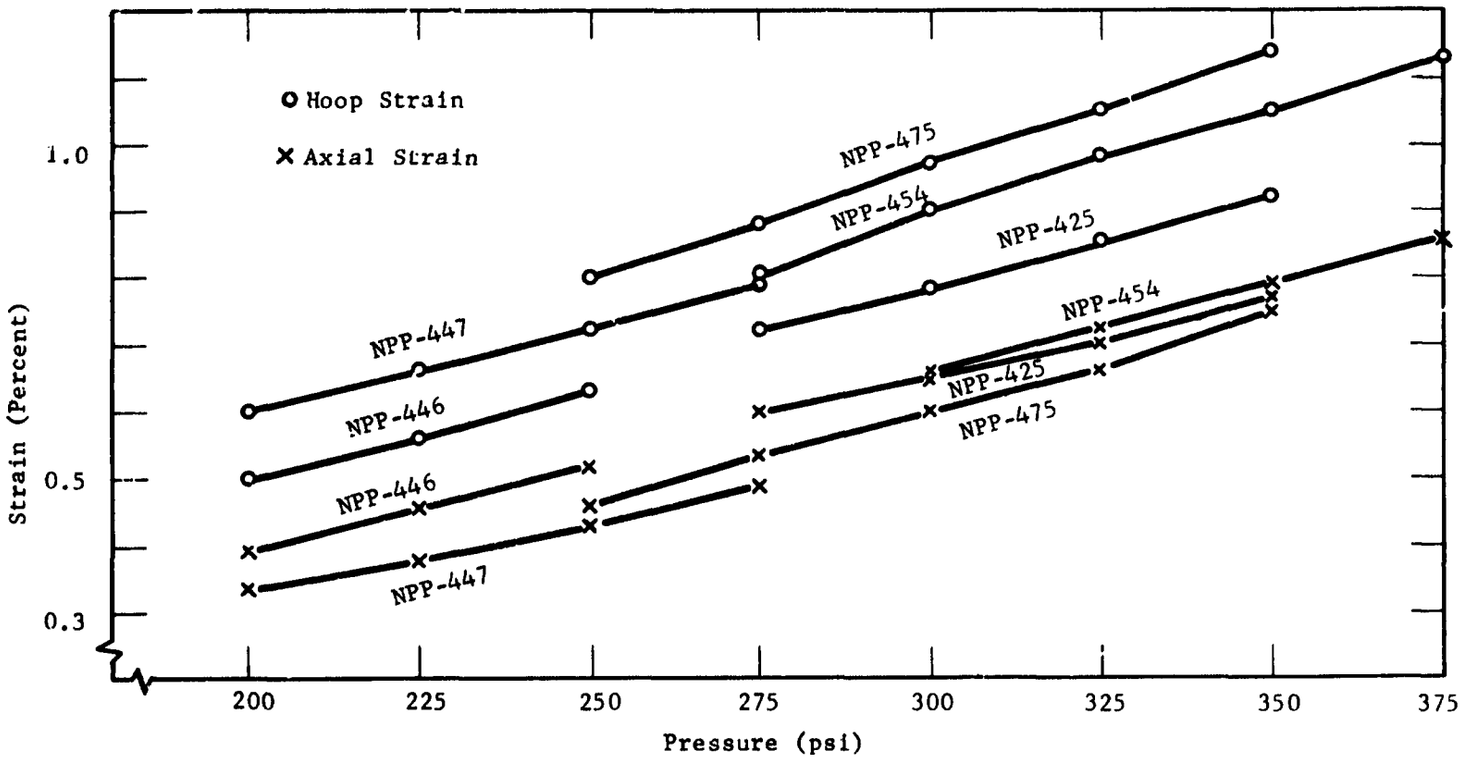
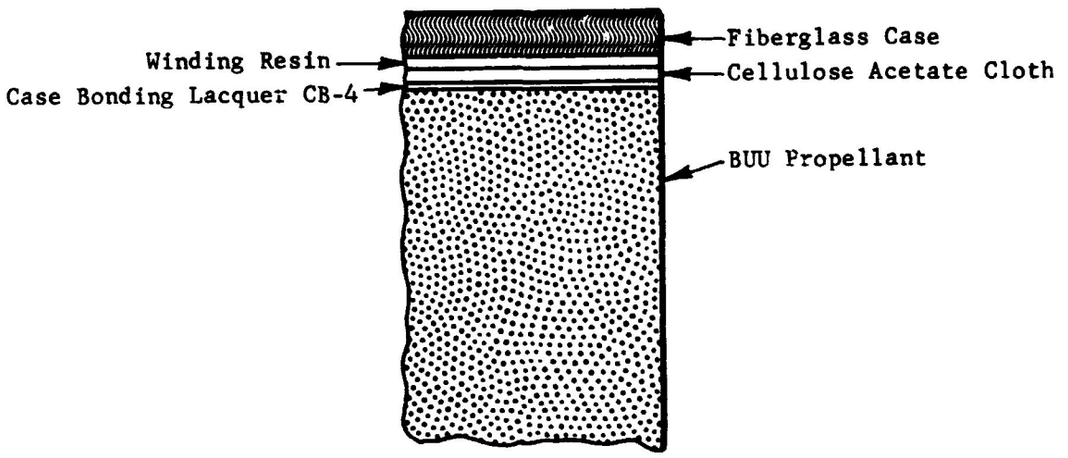


FIGURE 66 - HOOP AND AXIAL STRAIN VS. PRESSURE FOR X248 A6 CHAMBERS IN AREAS REMOTE FROM DEFECTS



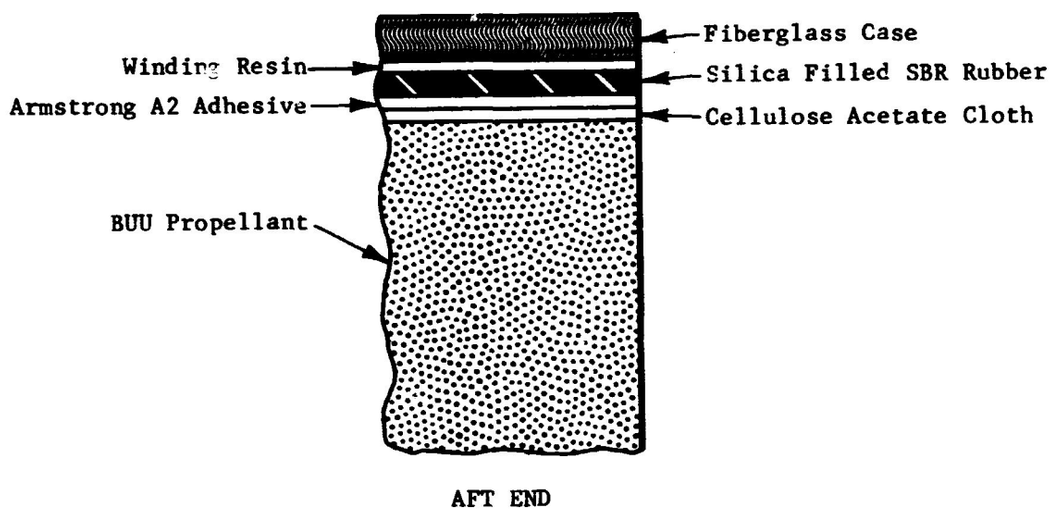


FIGURE 67 - X248 CASE BOND SYSTEM CROSS SECTION VIEW

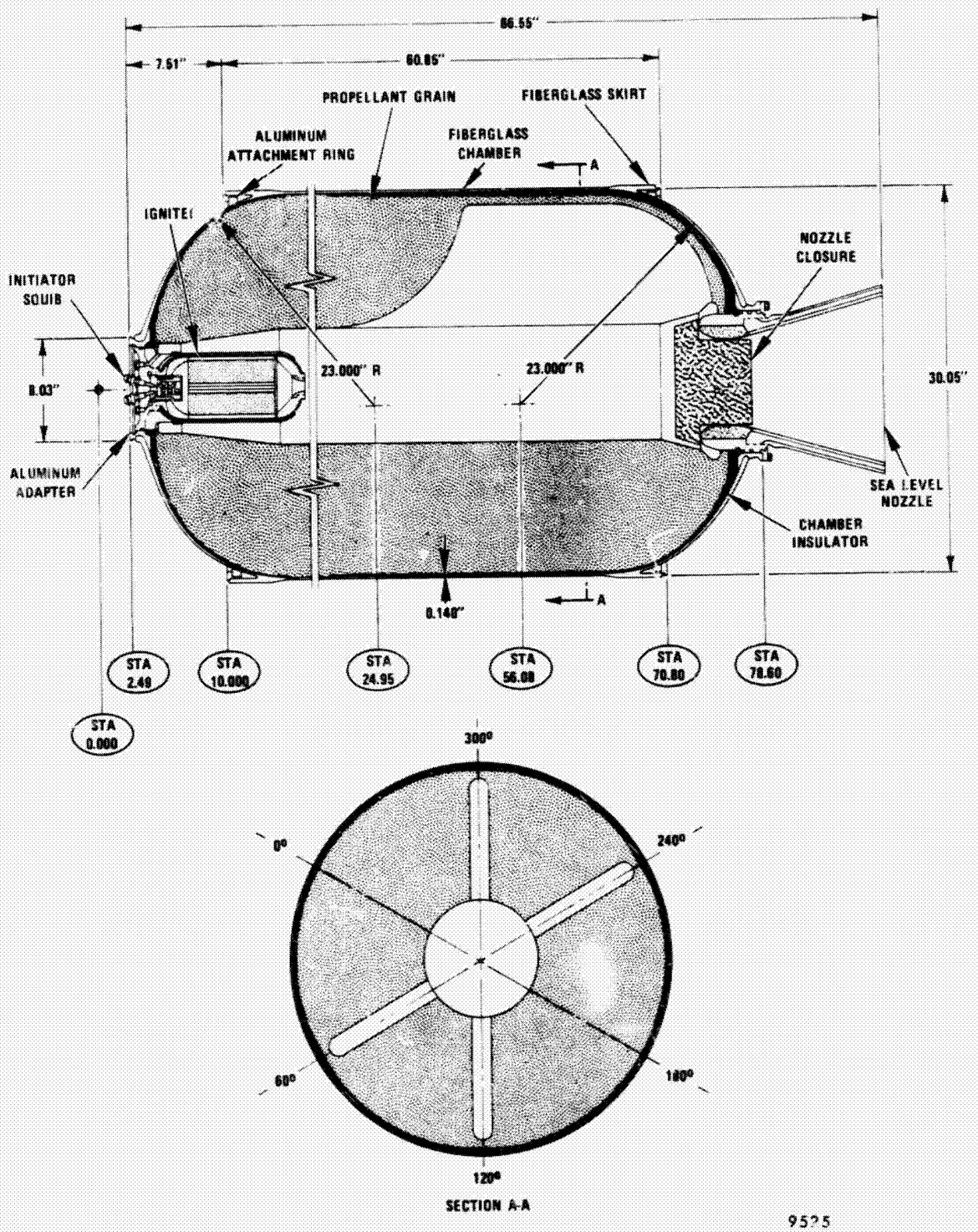


FIGURE 68 - ROCKET MOTOR X259

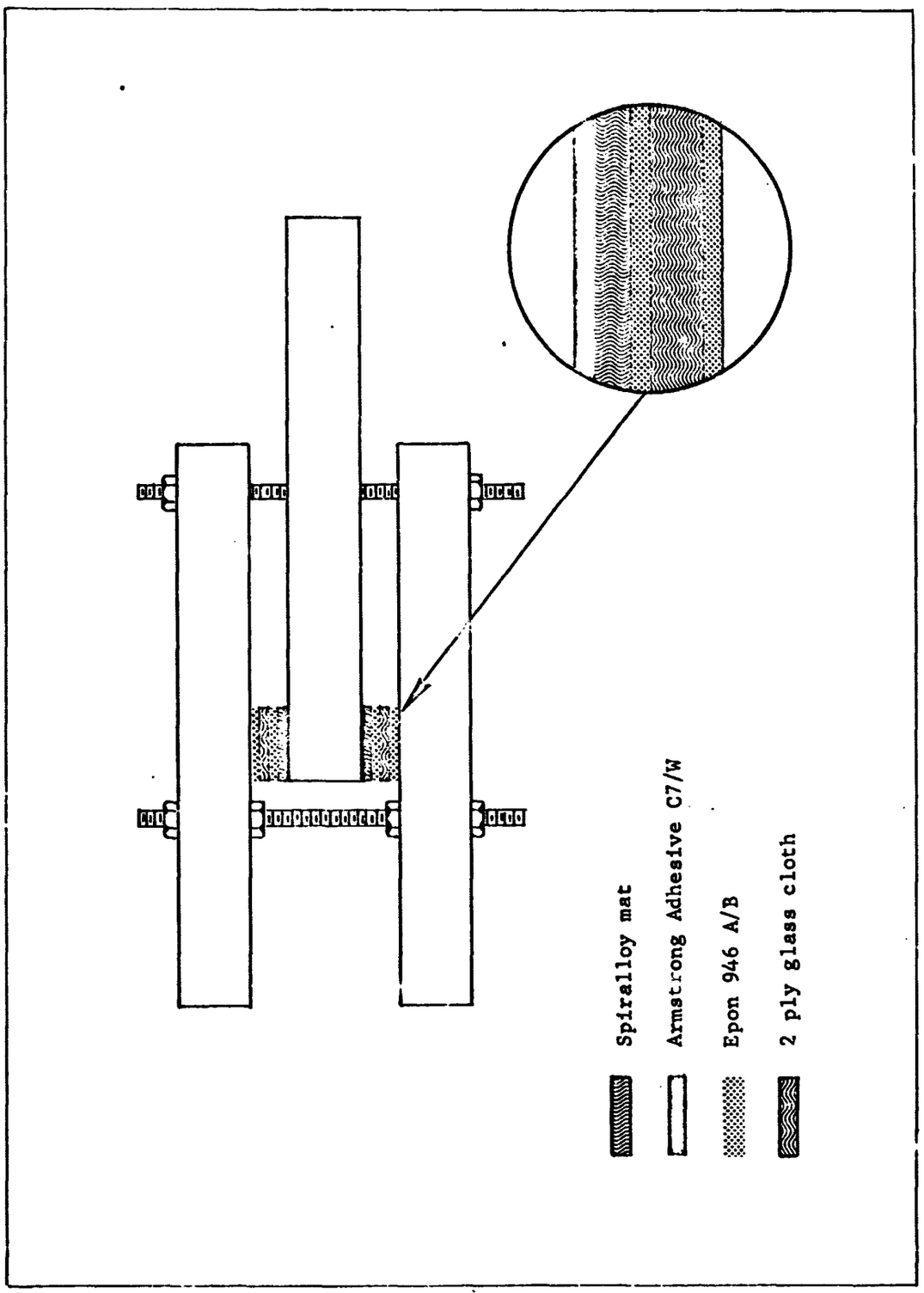


FIGURE 69 - THREE PLATE SHEAR SPECIMENS

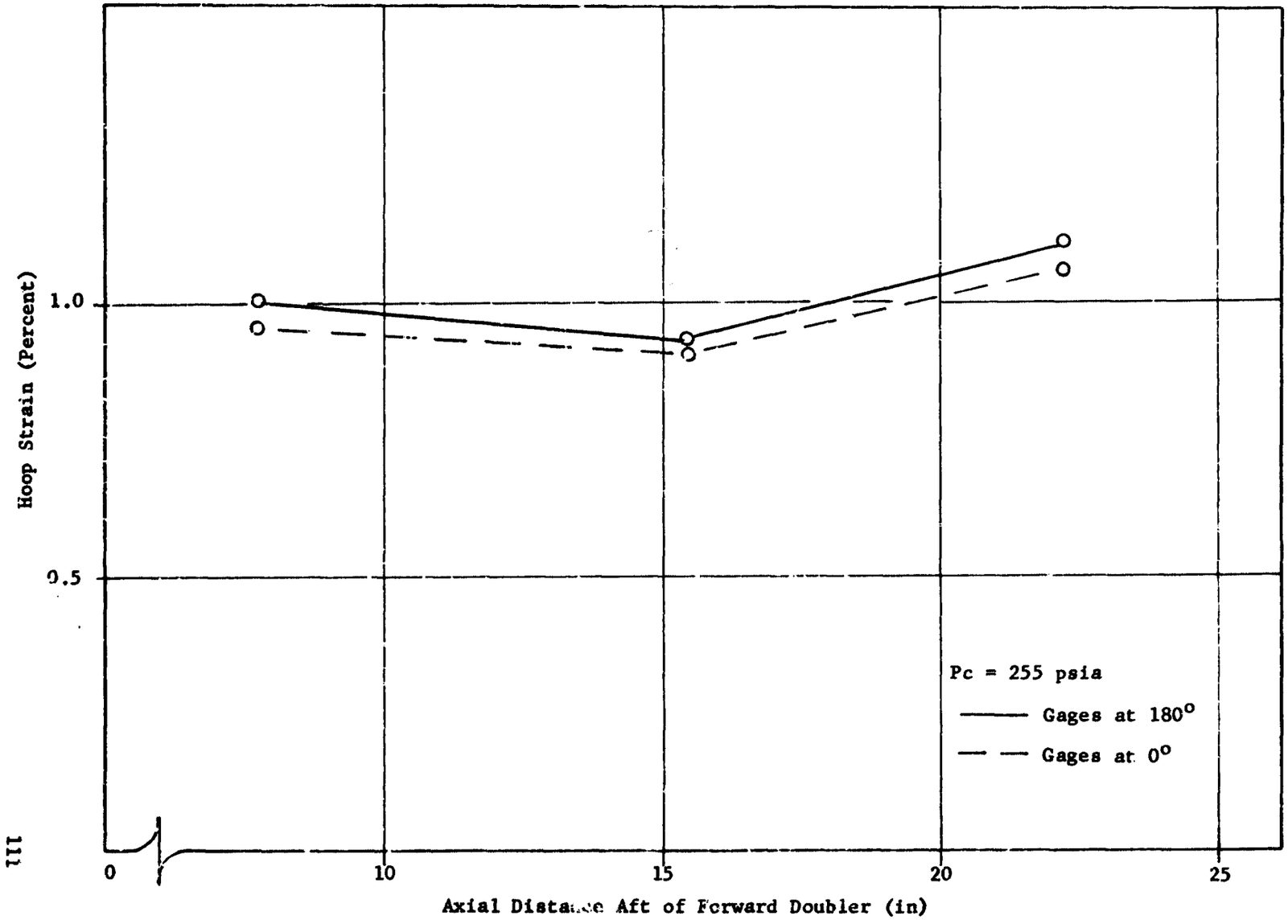


FIGURE 70 - HOOP STRAIN IN THE CYLINDRICAL SECTION OF NPP-400 (A5)

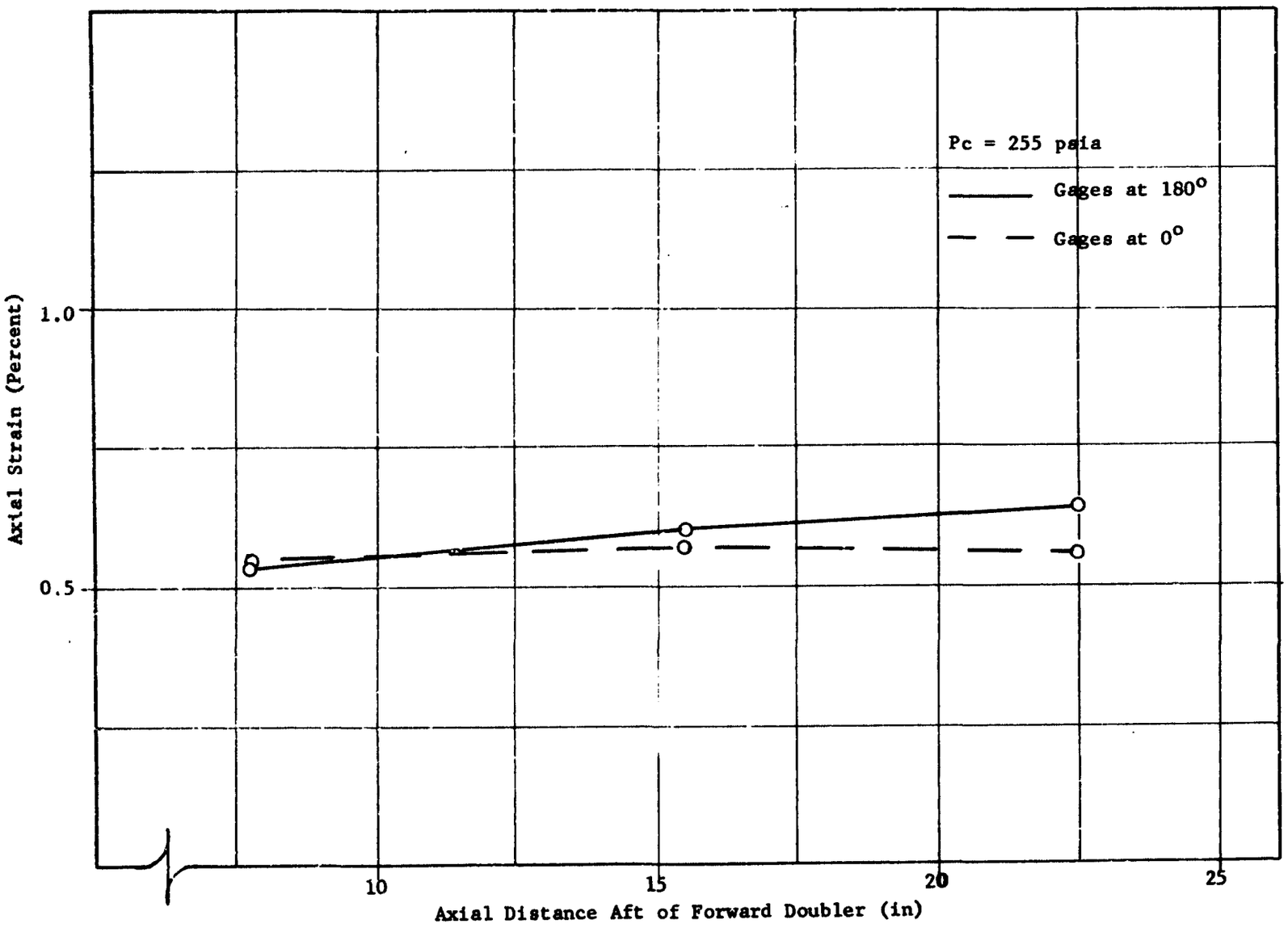


FIGURE 71 - AXIAL STRAIN IN THE CYLINDRICAL SECTION OF NPP-400 (A5)

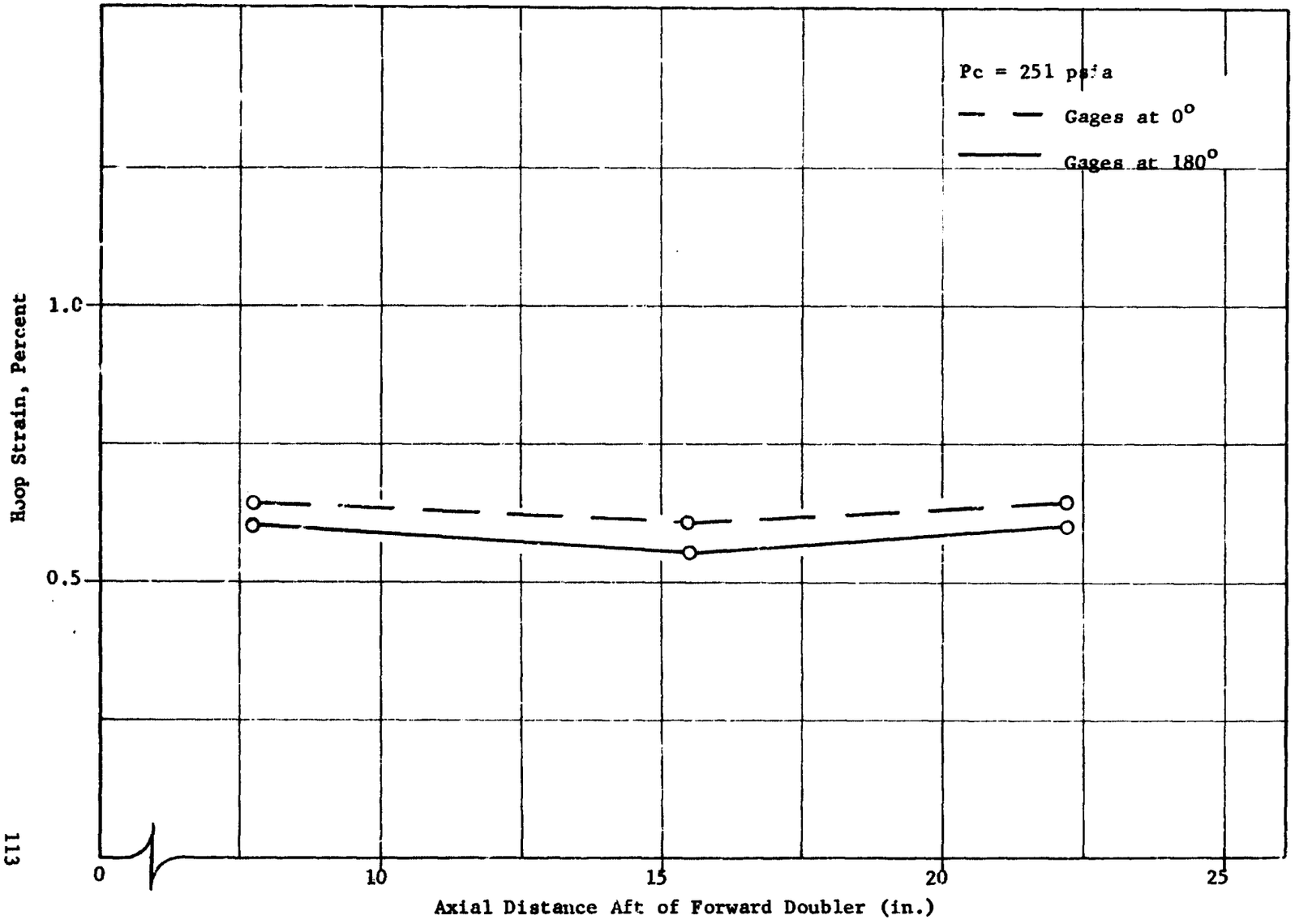


FIGURE 72 - HOOP STRAINS IN THE CYLINDRICAL SECTION OF NPP-446 (A6)

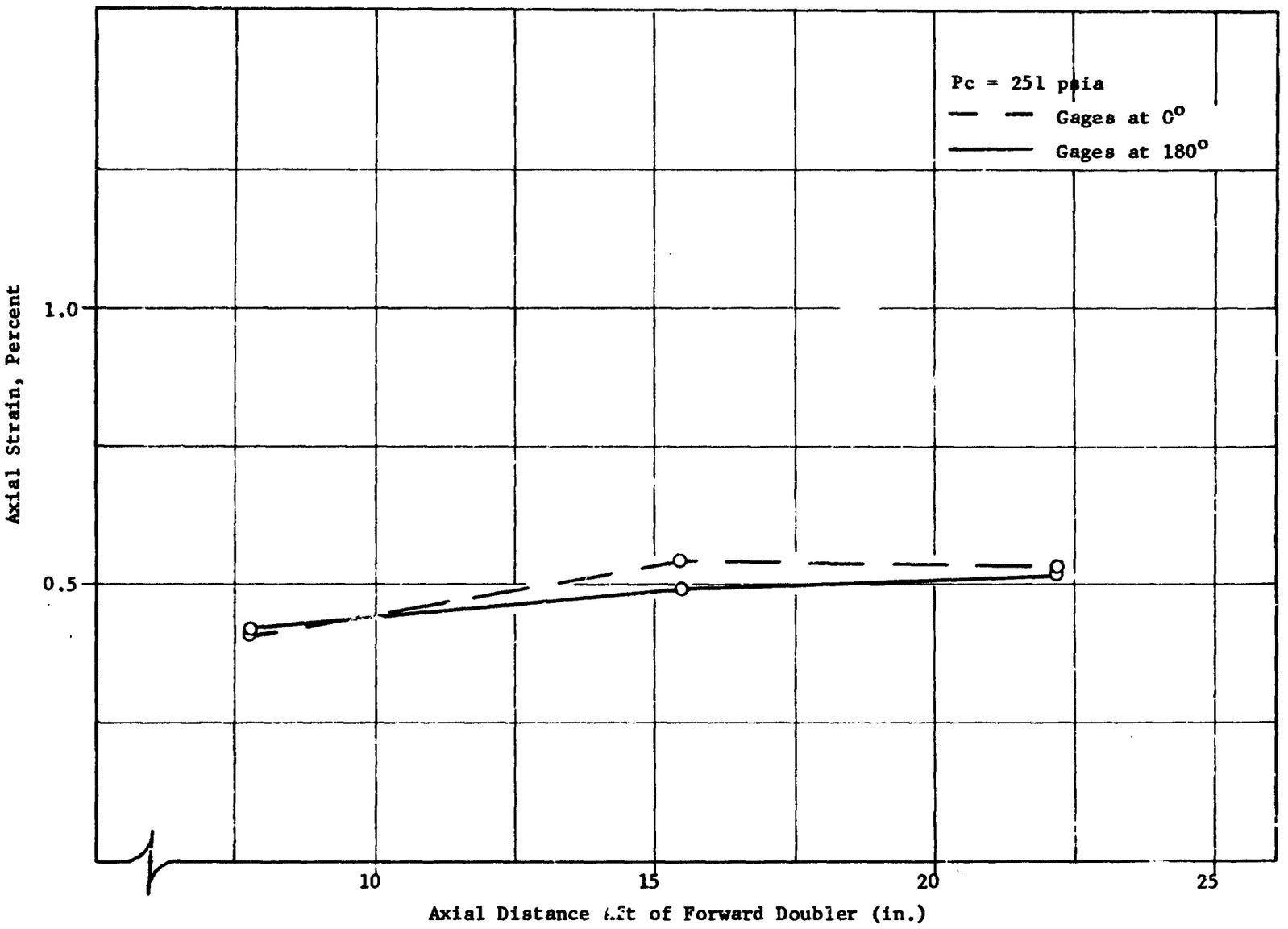


FIGURE 73 - AXIAL STRAINS IN THE CYLINDRICAL SECTION OF NPP-446 (A6)

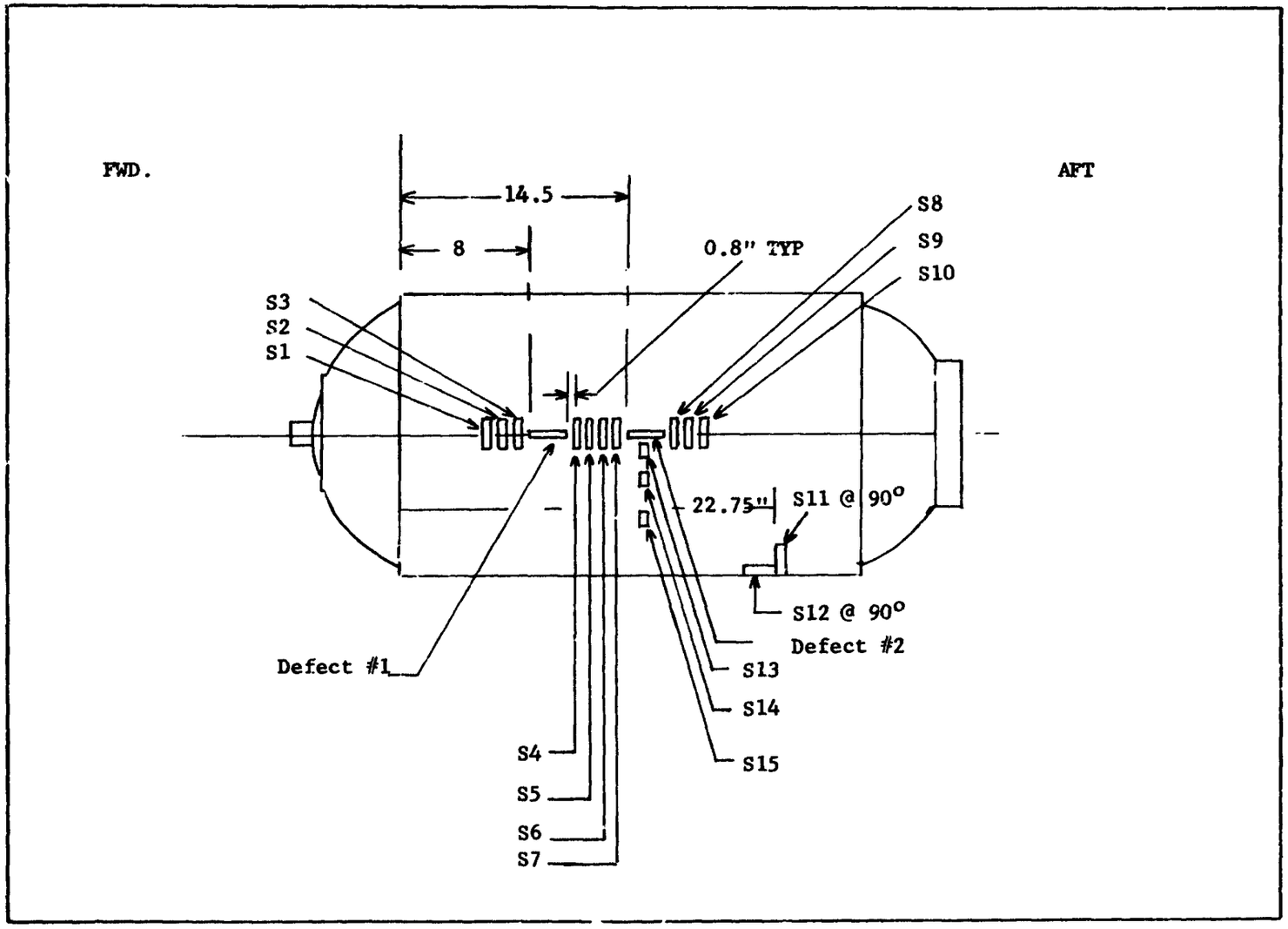


FIGURE 74 - STRAIN GAGE LOCATIONS X248 S/N NPP-409 (A5)

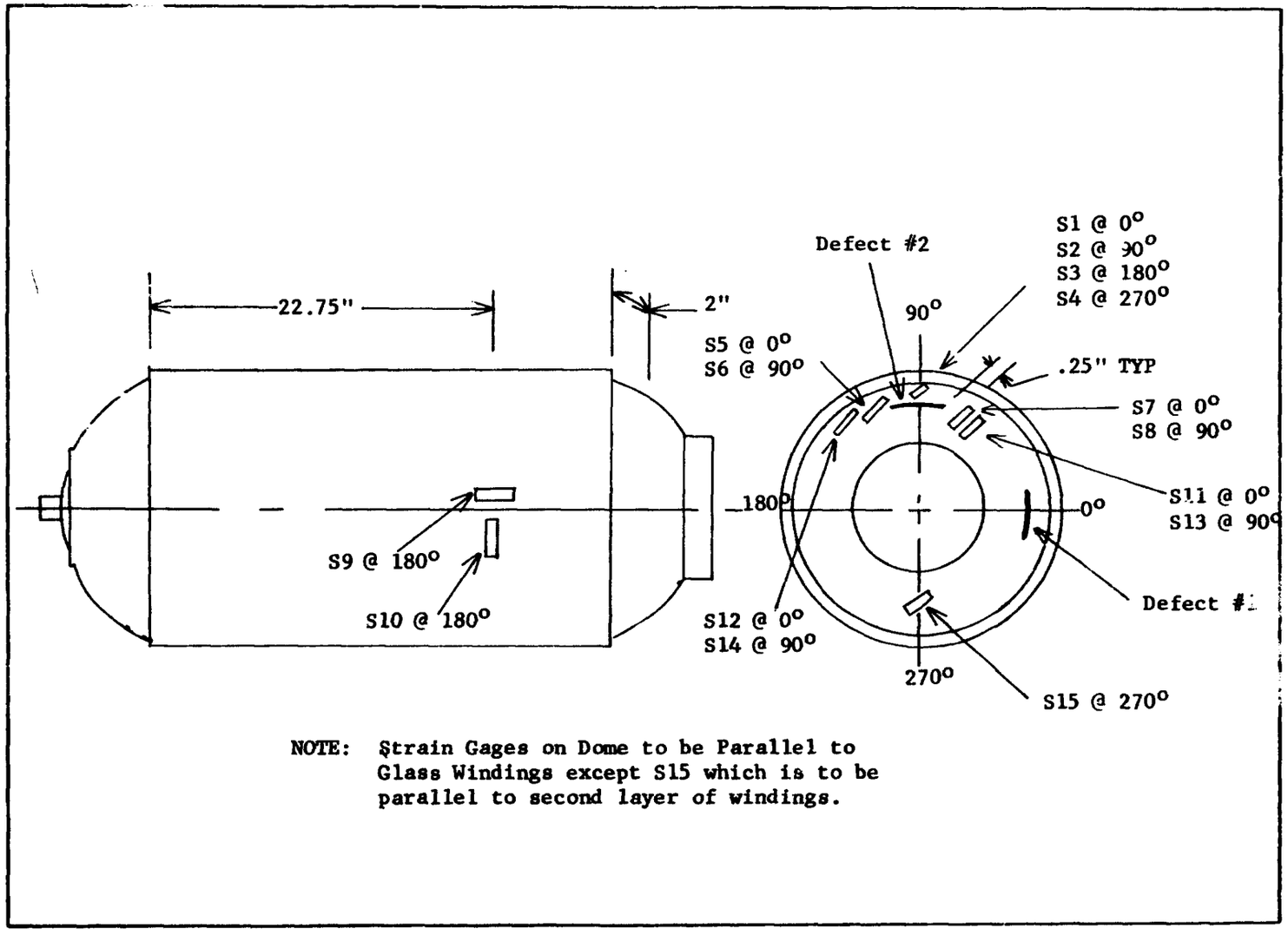


FIGURE 75 - STRAIN GAGE LOCATIONS X248 S/N NPP-447 (A6)

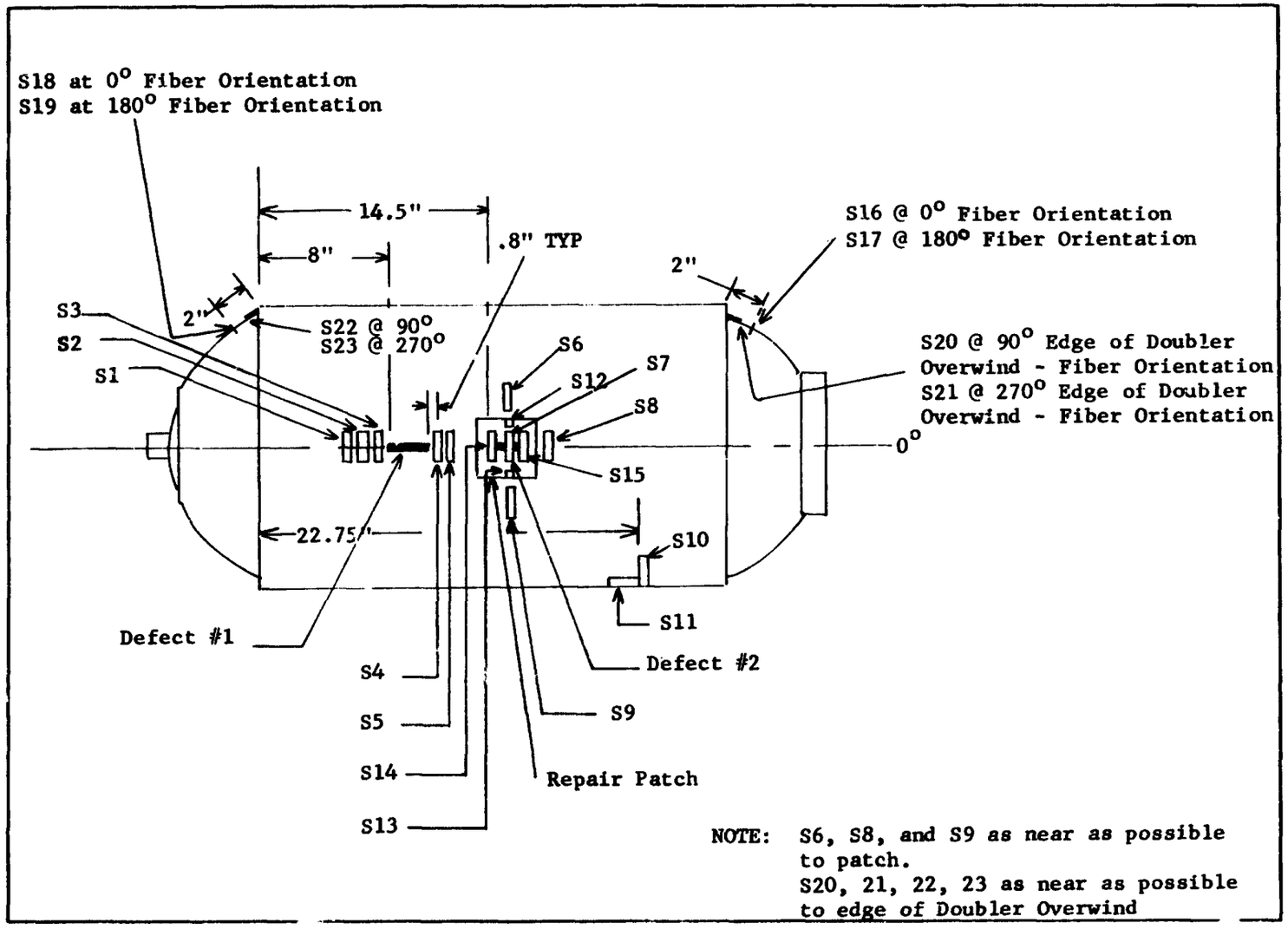


FIGURE 76 - STRAIN GAGE LOCATIONS X248 S/N NPP-401 (A5)
AND S/N NPP-257 (A5)

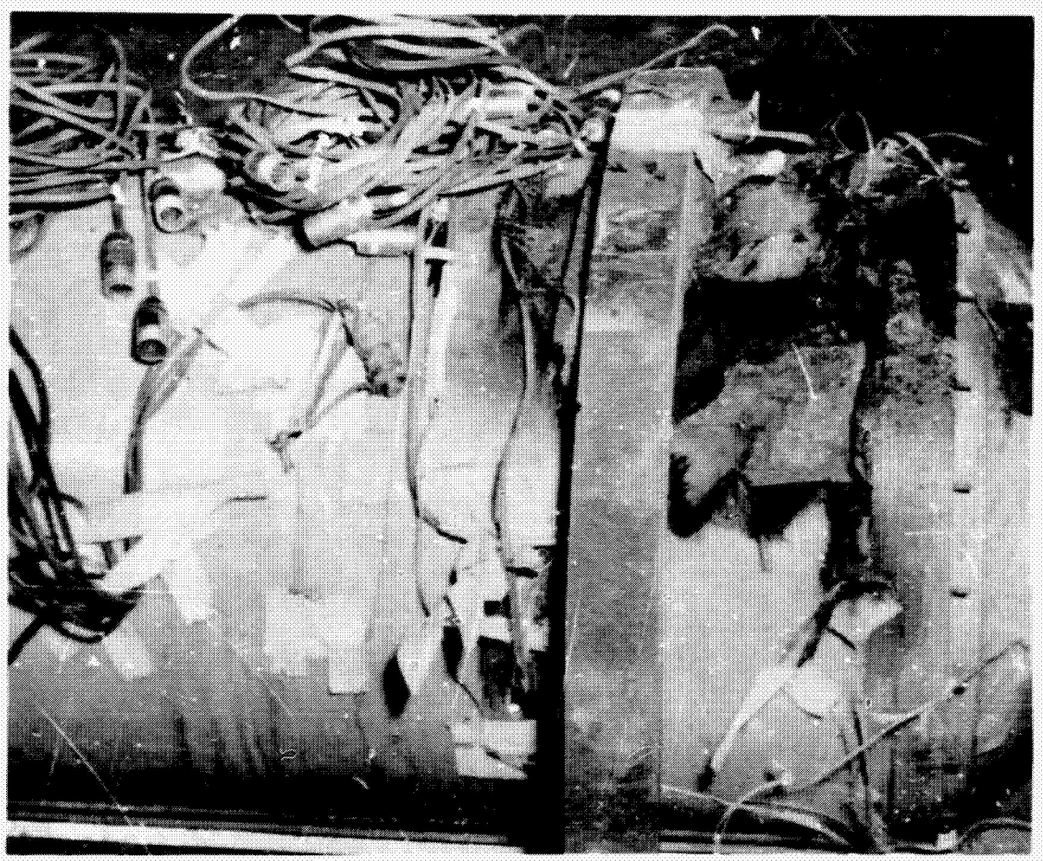


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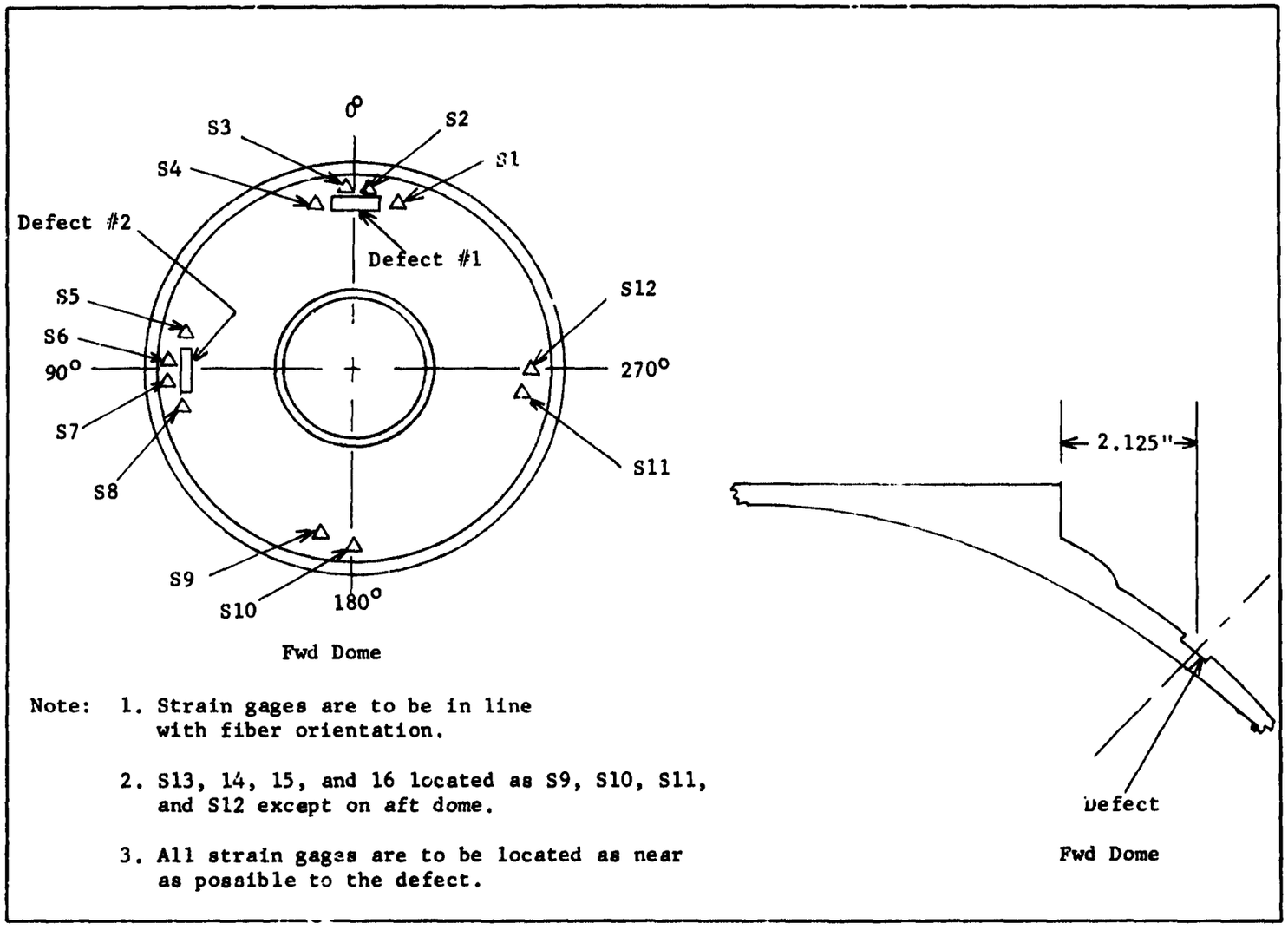
FIGURE 77 - AFT CYLINDRICAL FAILURE IN S/N NPP-401 (A5)



Note: 1. Strain gages are to be in line with fiber orientation.

2. S13, 14, 15, and 16 located as S9, S10, S11, and S12 except on aft dome.

3. All strain gages are to be located as near as possible to the defect.

FIGURE 78 - STRAIN GAGE AND DEFECT LOCATIONS X248 S/N NPP-455 (A6)

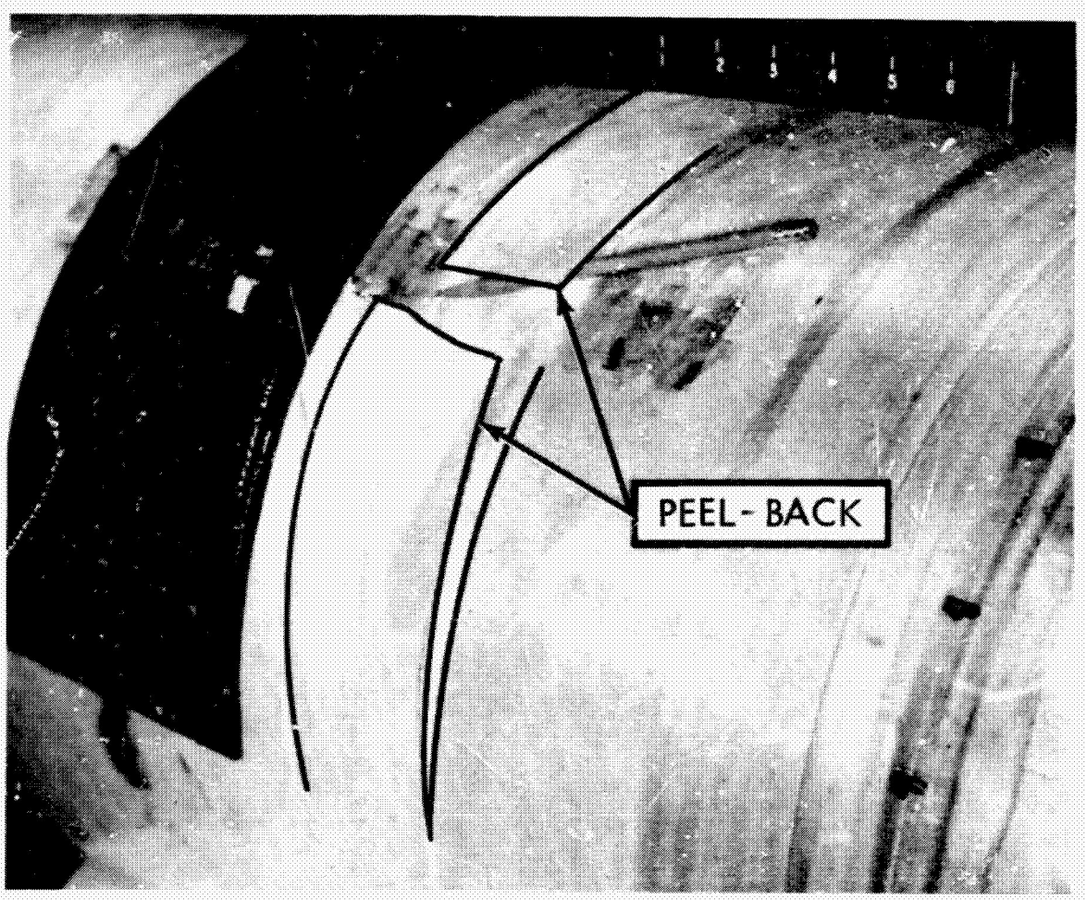


FIGURE 79 - POST-FIRE CYLINDRICAL DEFECTS ON NPP-257 (A5)

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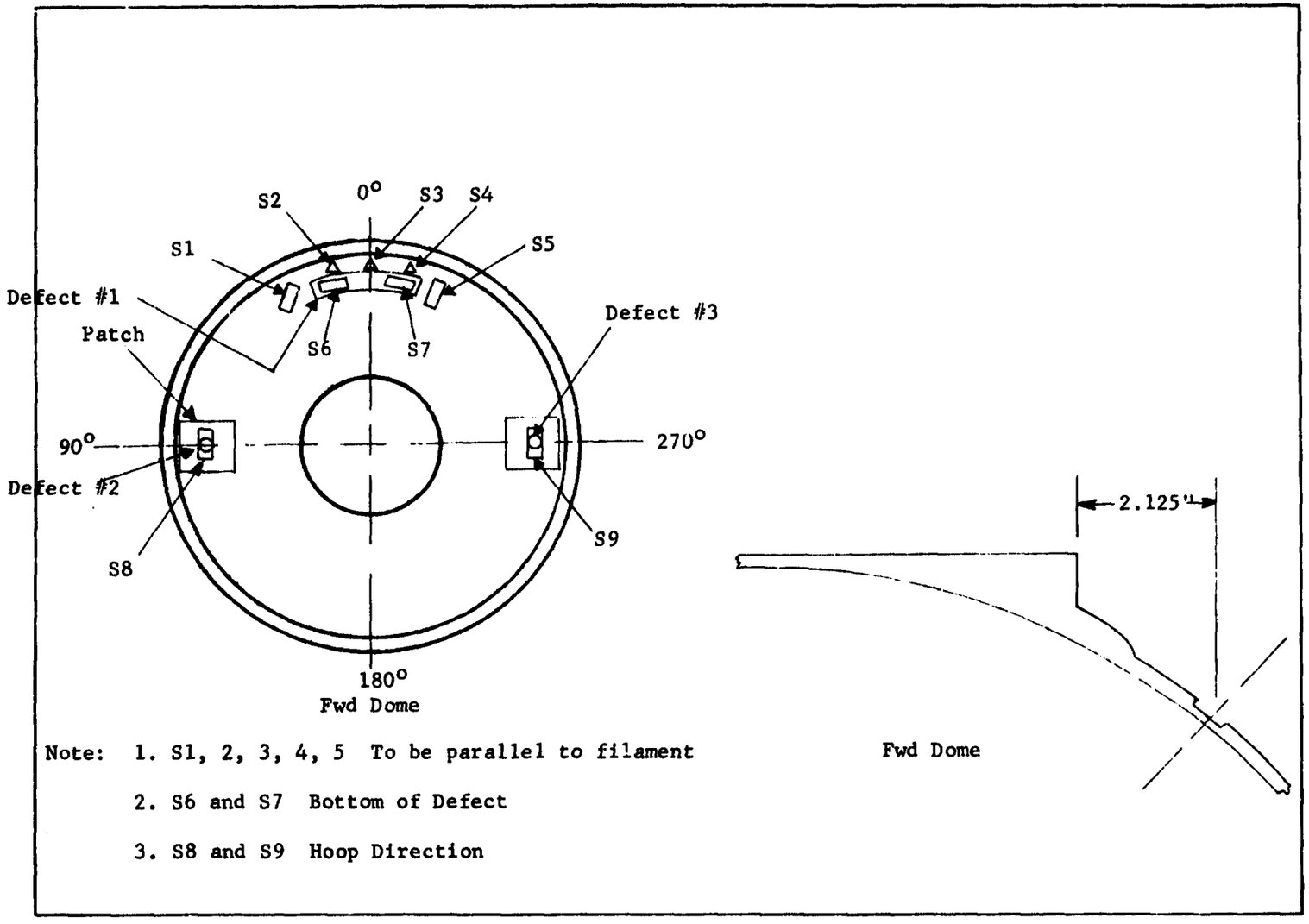
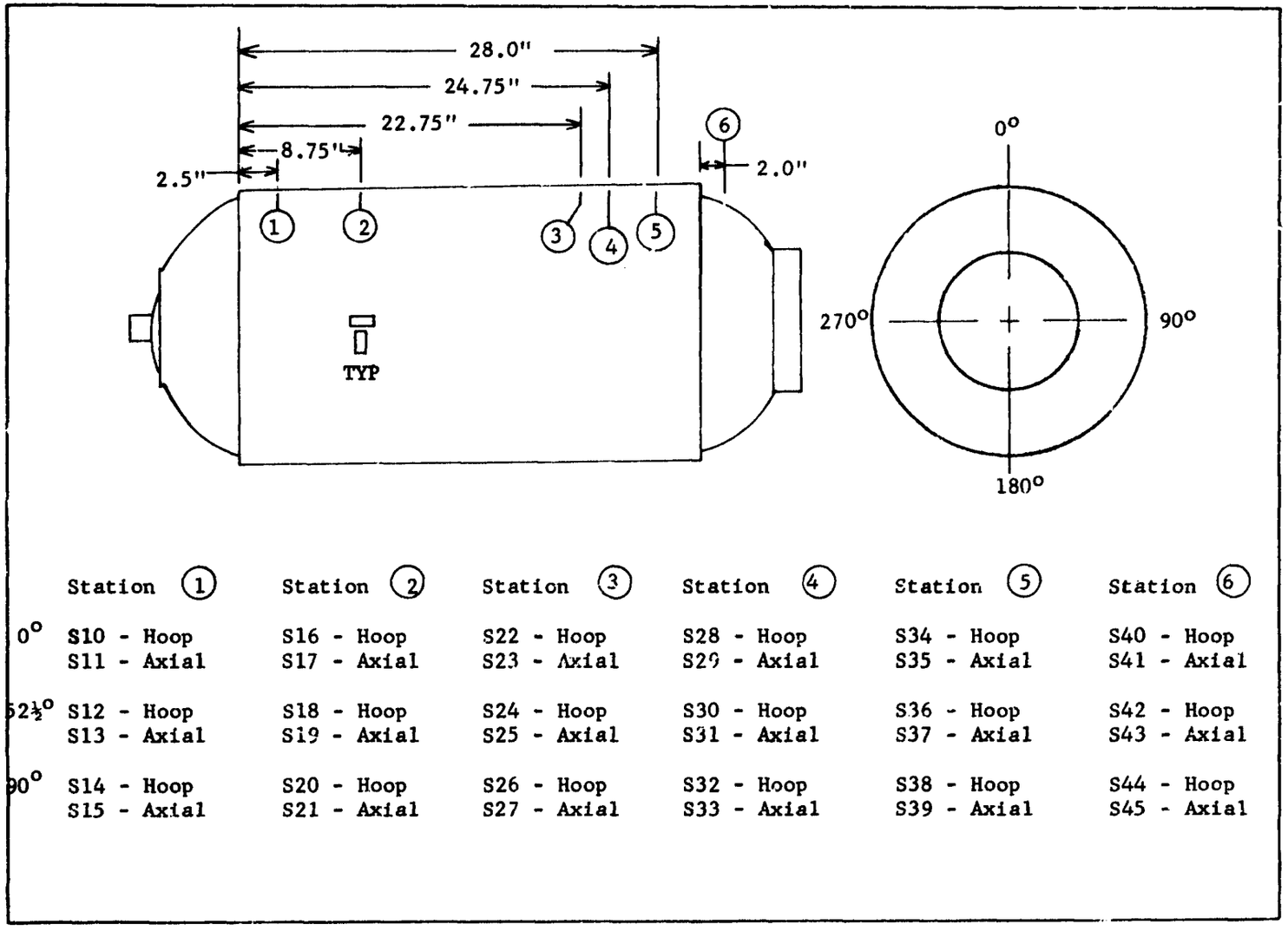


Note: 1. S1, 2, 3, 4, 5 To be parallel to filament

2. S6 and S7 Bottom of Defect

3. S8 and S9 Hoop Direction

FIGURE 80 - STRAIN GAGE LOCATION FWD DOME X248 S/N NPP-454 (A6)



	Station (1)	Station (2)	Station (3)	Station (4)	Station (5)	Station (6)
0°	S10 - Hoop S11 - Axial	S16 - Hoop S17 - Axial	S22 - Hoop S23 - Axial	S28 - Hoop S29 - Axial	S34 - Hoop S35 - Axial	S40 - Hoop S41 - Axial
52½°	S12 - Hoop S13 - Axial	S18 - Hoop S19 - Axial	S24 - Hoop S25 - Axial	S30 - Hoop S31 - Axial	S36 - Hoop S37 - Axial	S42 - Hoop S43 - Axial
90°	S14 - Hoop S15 - Axial	S20 - Hoop S21 - Axial	S26 - Hoop S27 - Axial	S32 - Hoop S33 - Axial	S38 - Hoop S39 - Axial	S44 - Hoop S45 - Axial

FIGURE 81 - STRAIN GAGE LOCATIONS CYLINDRICAL SECTION X248 S/N NPP-454 (A6)

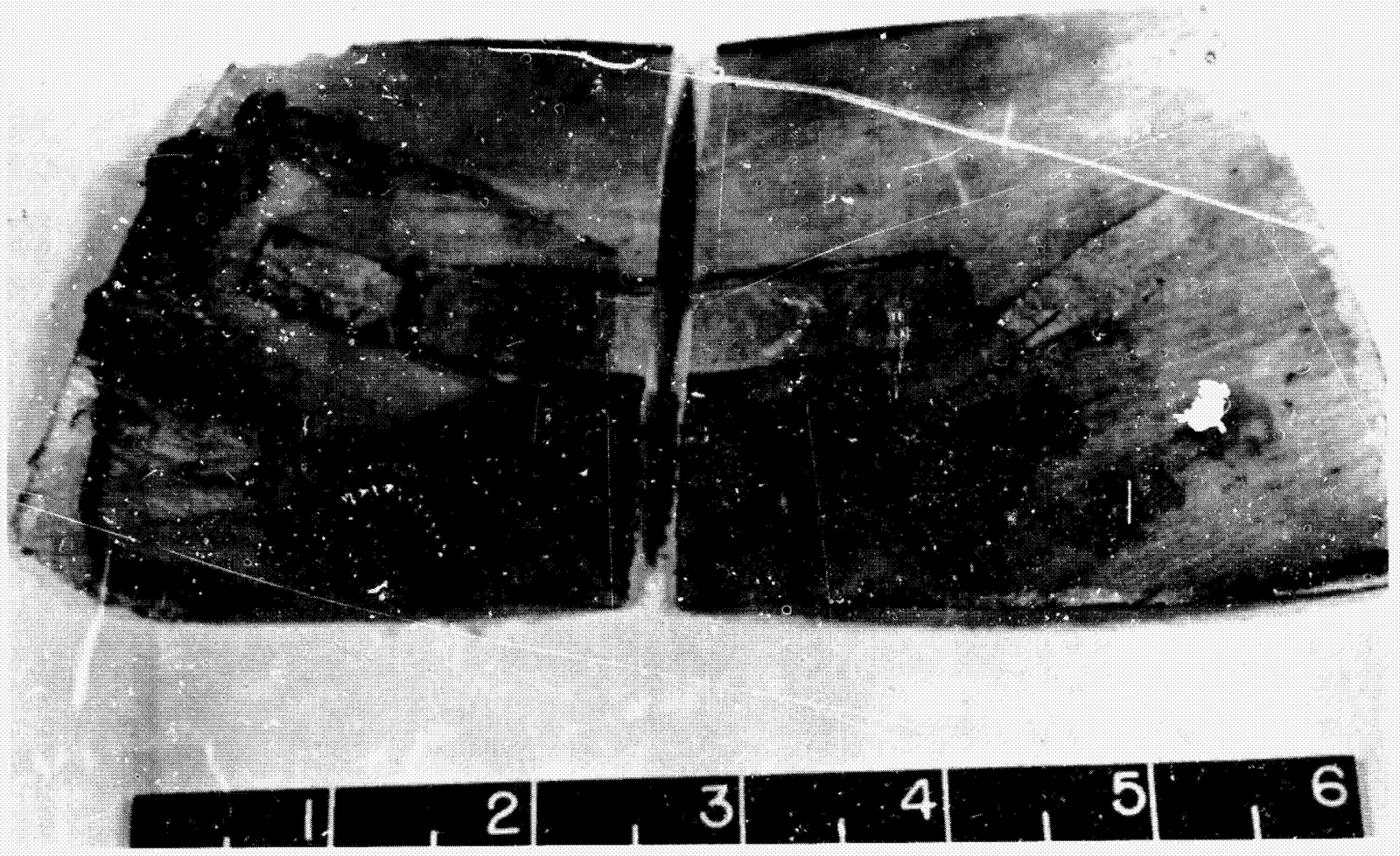


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FIGURE 82 - TOP VIEW OF FORWARD DOME DEFECT ON NPP-454 (A6)

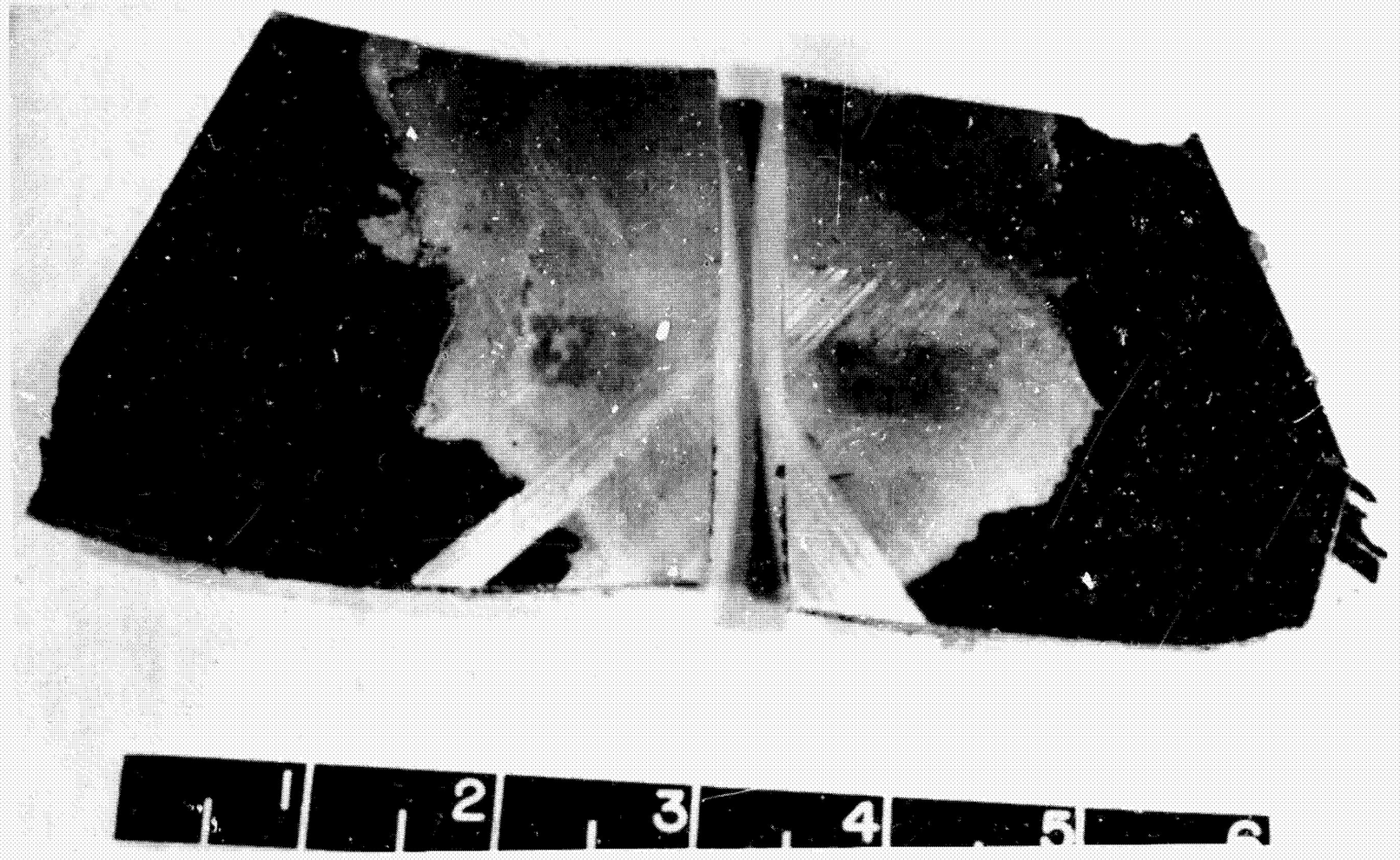

FIGURE 83 - UNDERSIDE VIEW OF FORWARD DOME DEFECT ON NPP-454 (A6)

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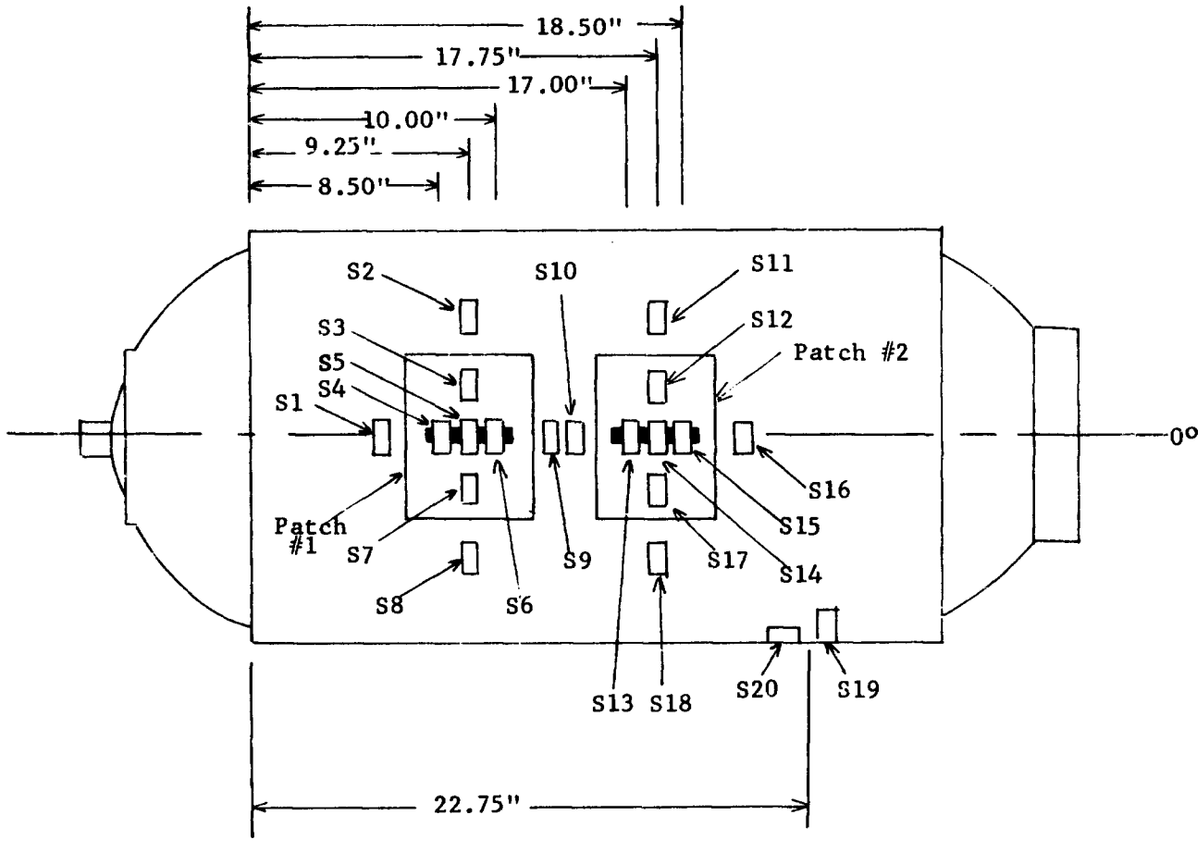


Note: 1. Defect #1 8" Aft of forward face of forward doubler
2. Defect #2 16.5" Aft of forward face of forward doubler

FIGURE 84 - STRAIN GAGE LOCATIONS X248 S/N NPP-261(A5)

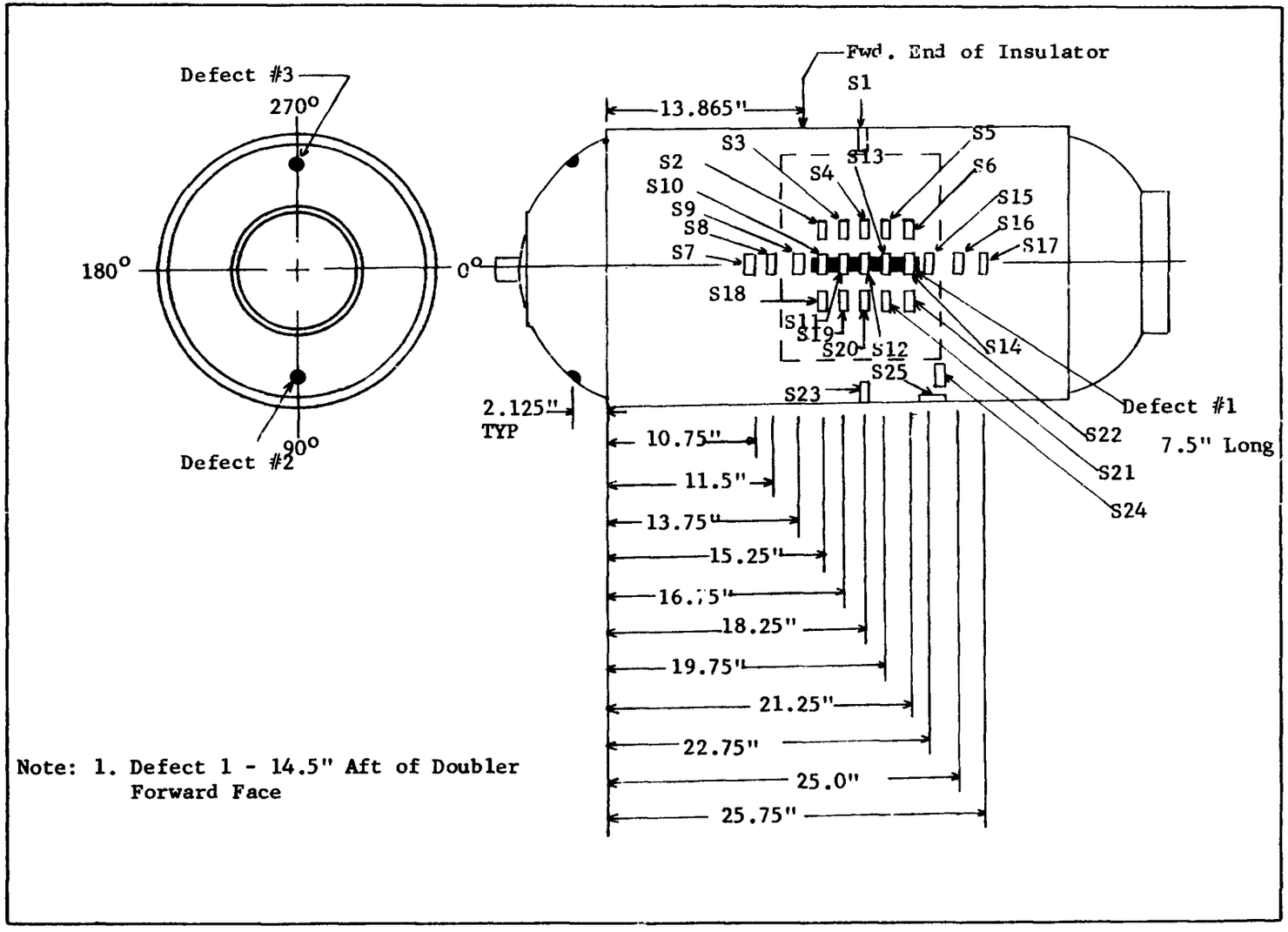
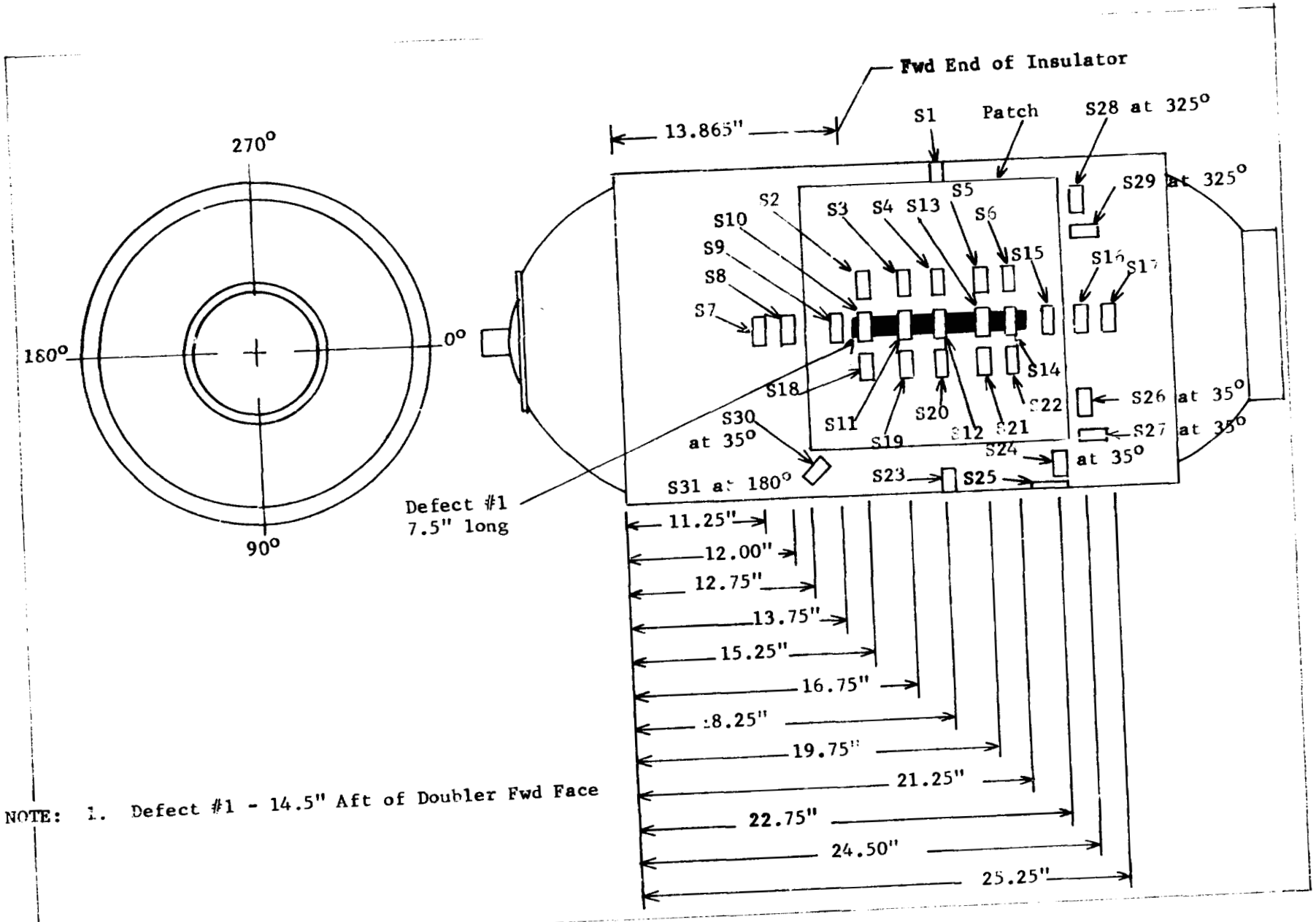


FIGURE 85 - STRAIN GAGE LOCATIONS X248 S/N NPP-242 (A5)



NOTE: 1. Defect #1 - 14.5" Aft of Doubler Fwd Face

FIGURE 86 STRAIN GAGE LOCATIONS X248 S/N NPP-475 (A6)

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FIGURE 87 - POST-FIRING PICTURE OF FAILURE IN NPP-475 (A6)

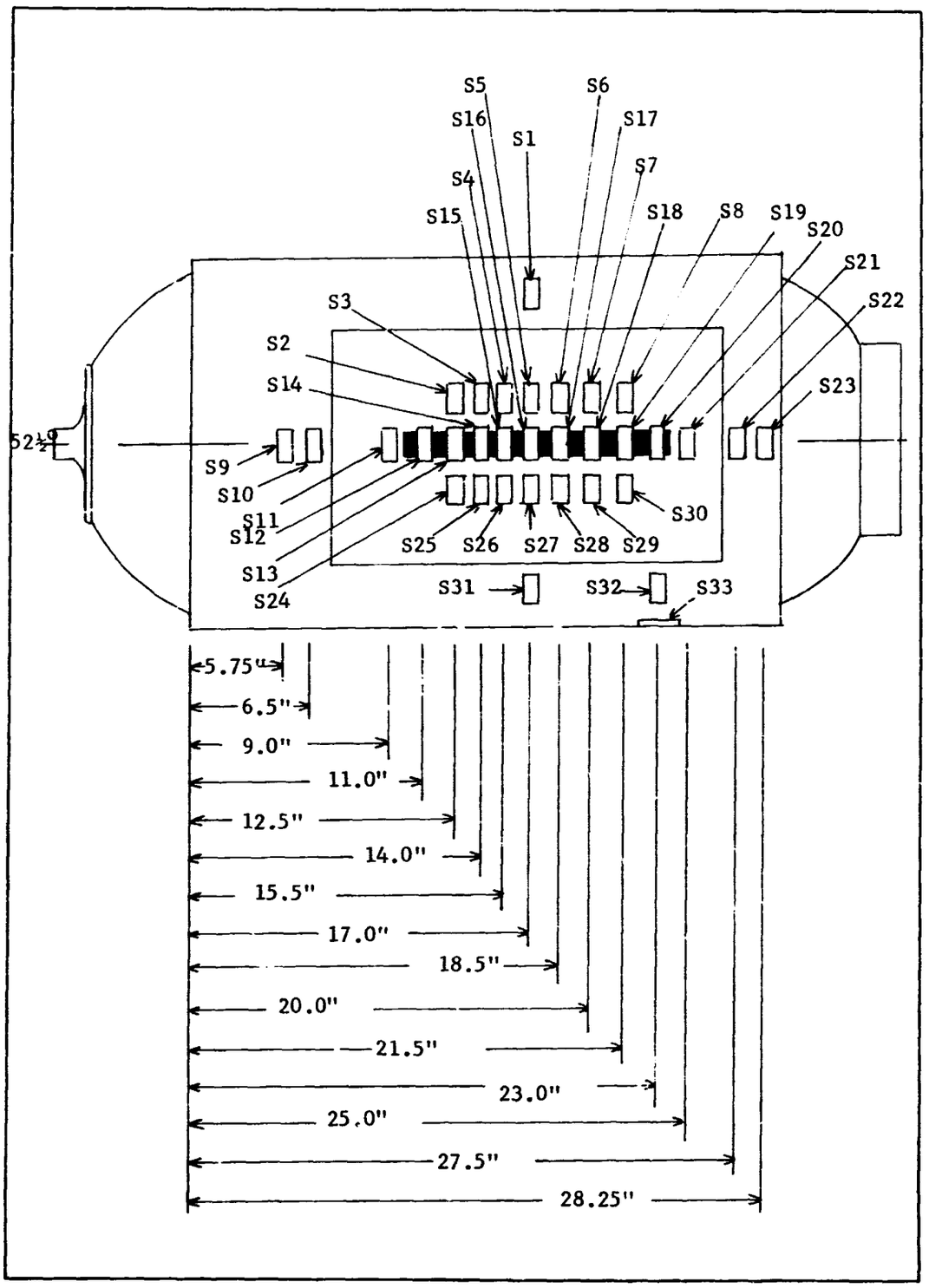


FIGURE 88 - STRAIN GAGE LOCATIONS X248 S/N NPP-425 (A6)

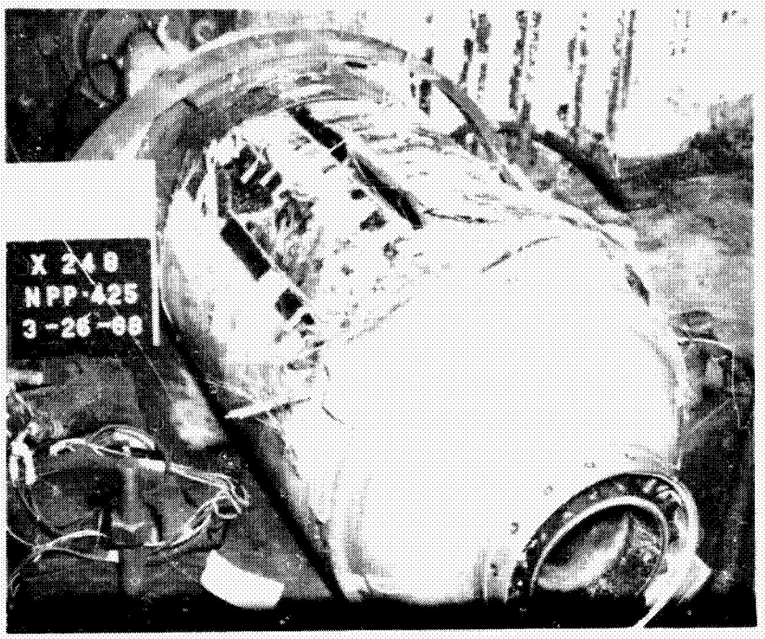


FIGURE 89 - POST-FIRING PICTURE OF S/N-425 (A6)

FIGURE 90 - POST-FIRING PICTURE OF S/N-425 (A6)

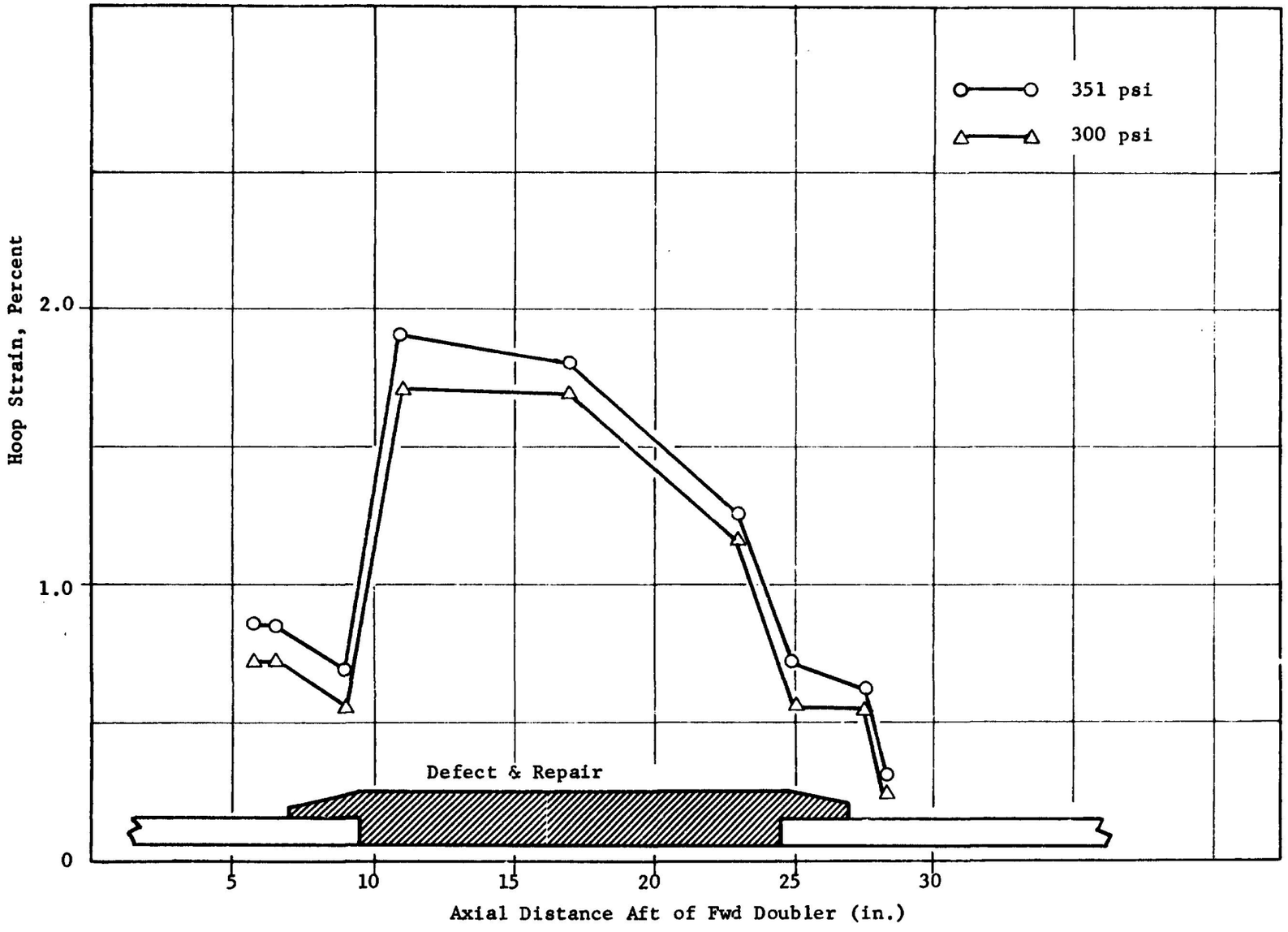


FIGURE 91 - HOOP STRAIN VS. PRESSURE X248 S/N NPP-425 (A6)

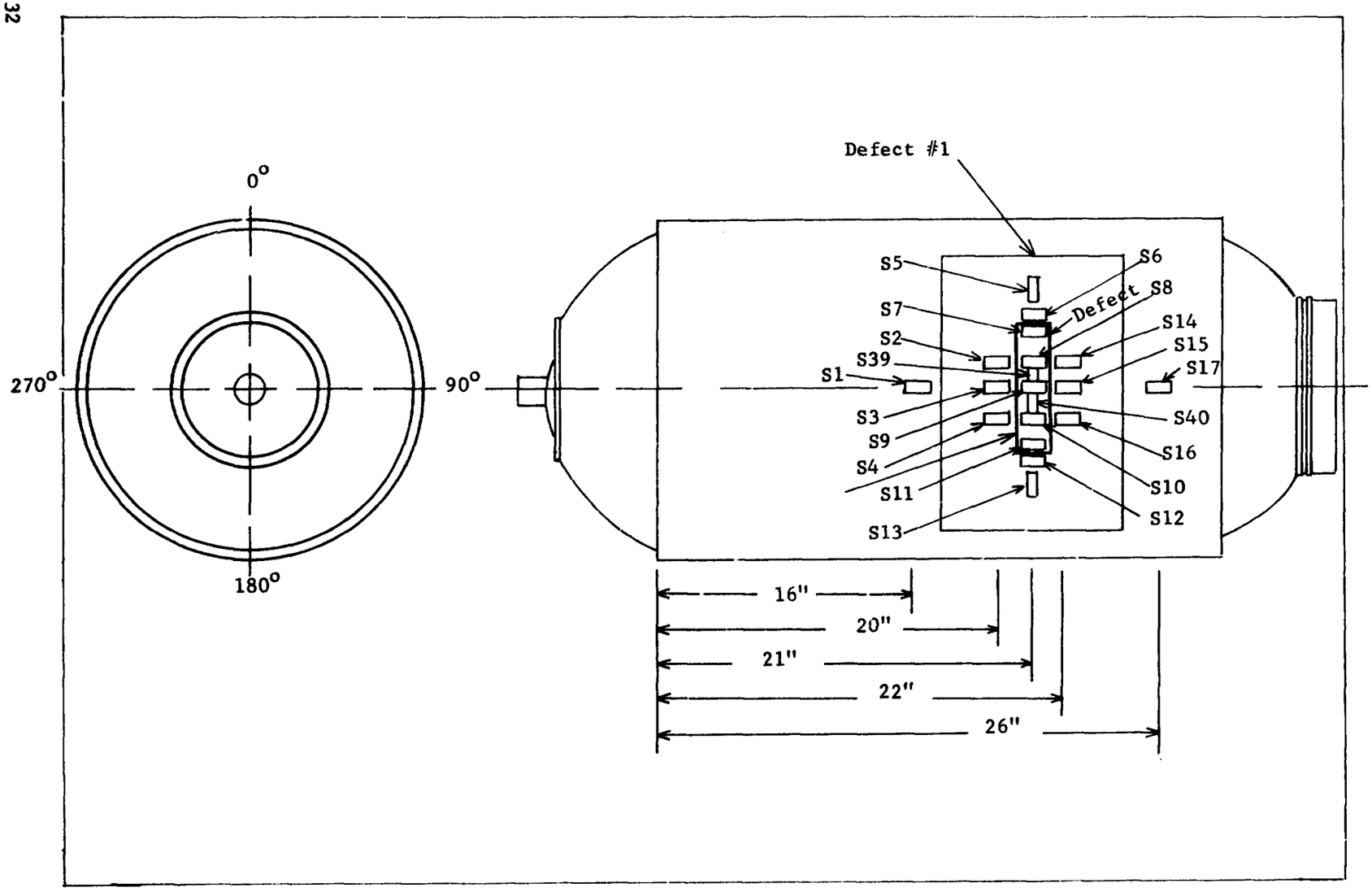


FIGURE 92 - STRAIN GAGE LOCATIONS X248 S/N NPP-445 (A6)

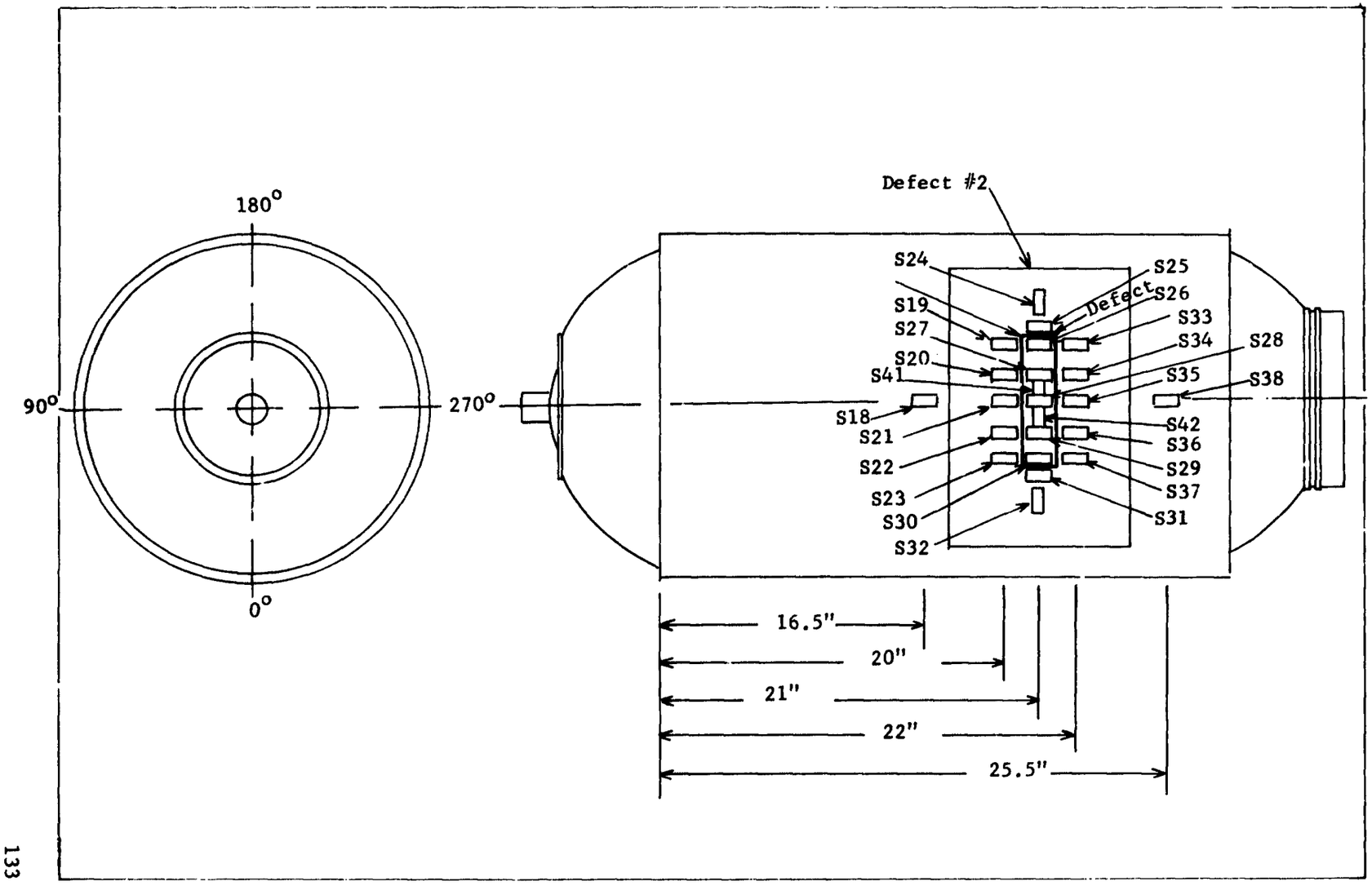


FIGURE 93 - STRAIN GAGE LOCATIONS X248 S/N NPP-445 (A6)

FIGURE 94 - DEFECT NO. 1 ON X248 A6 S/N - 453 - CYLINDRICAL SECTION

G-2334

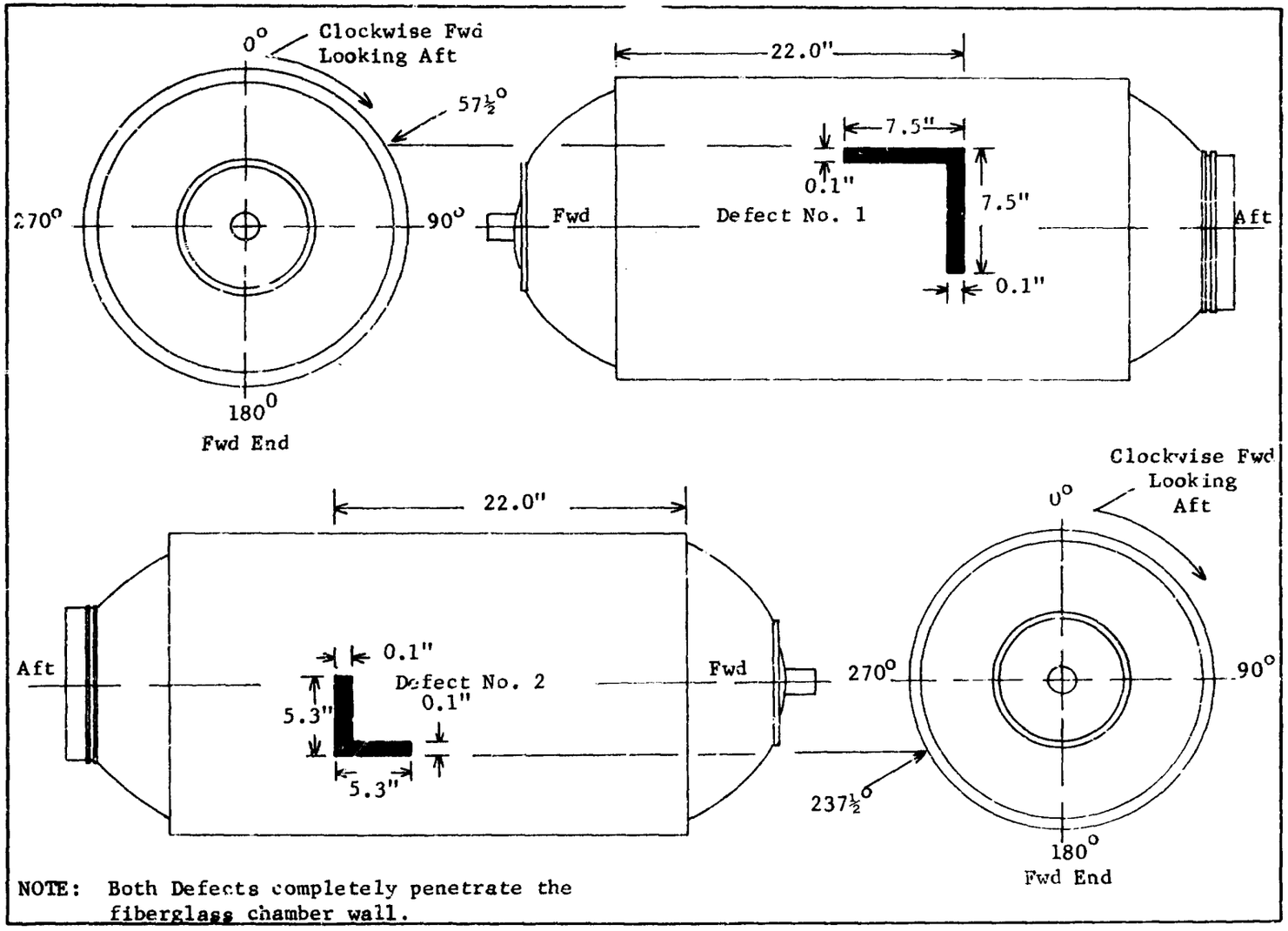


FIGURE 95 - DEFECT LOCATIONS X248 S/N NPP-453 (A6)

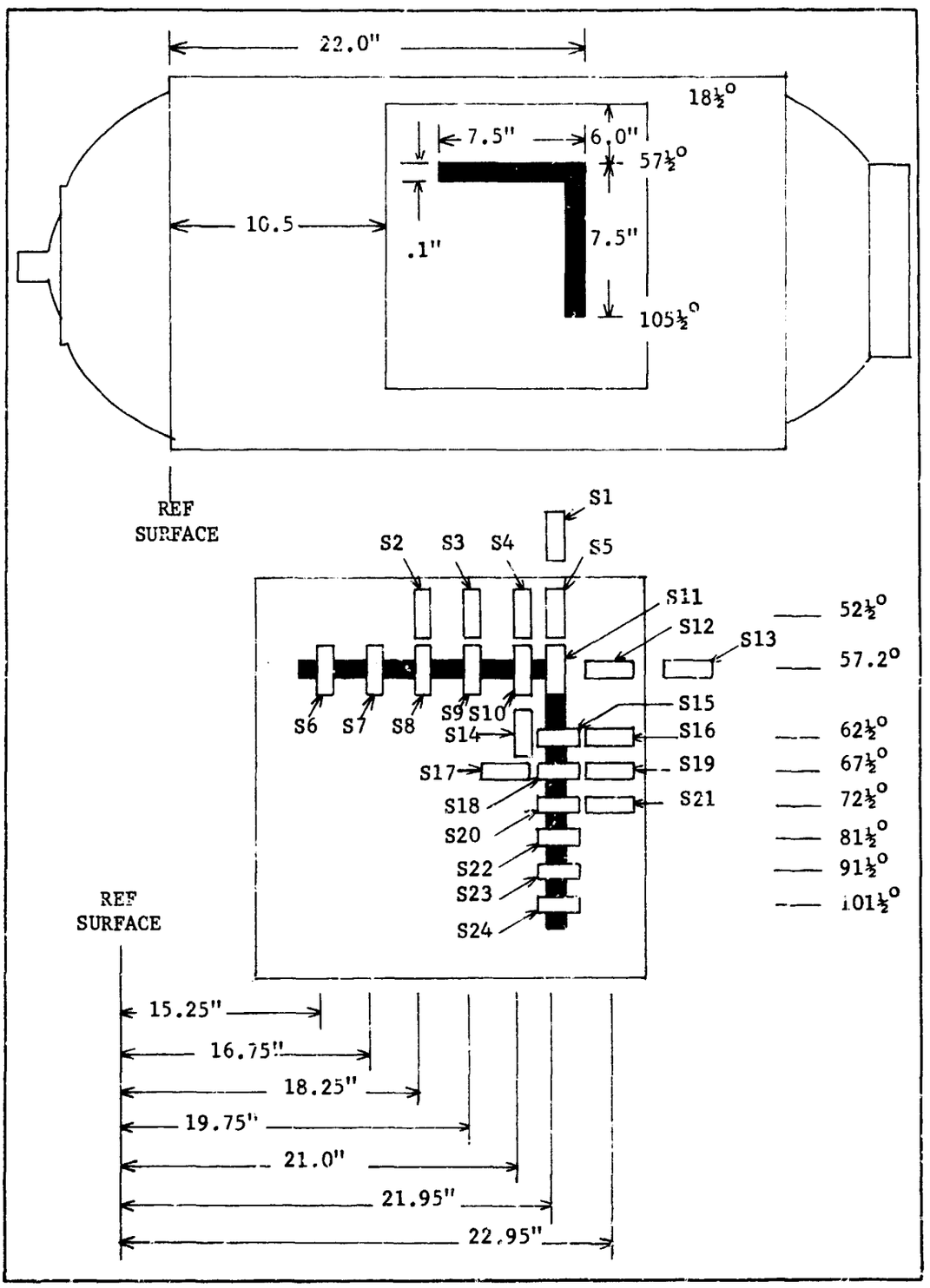


FIGURE 96 - STRAIN GAGE LOCATIONS X248 S/N NPP-453 (A5) DEFECT NO. 1

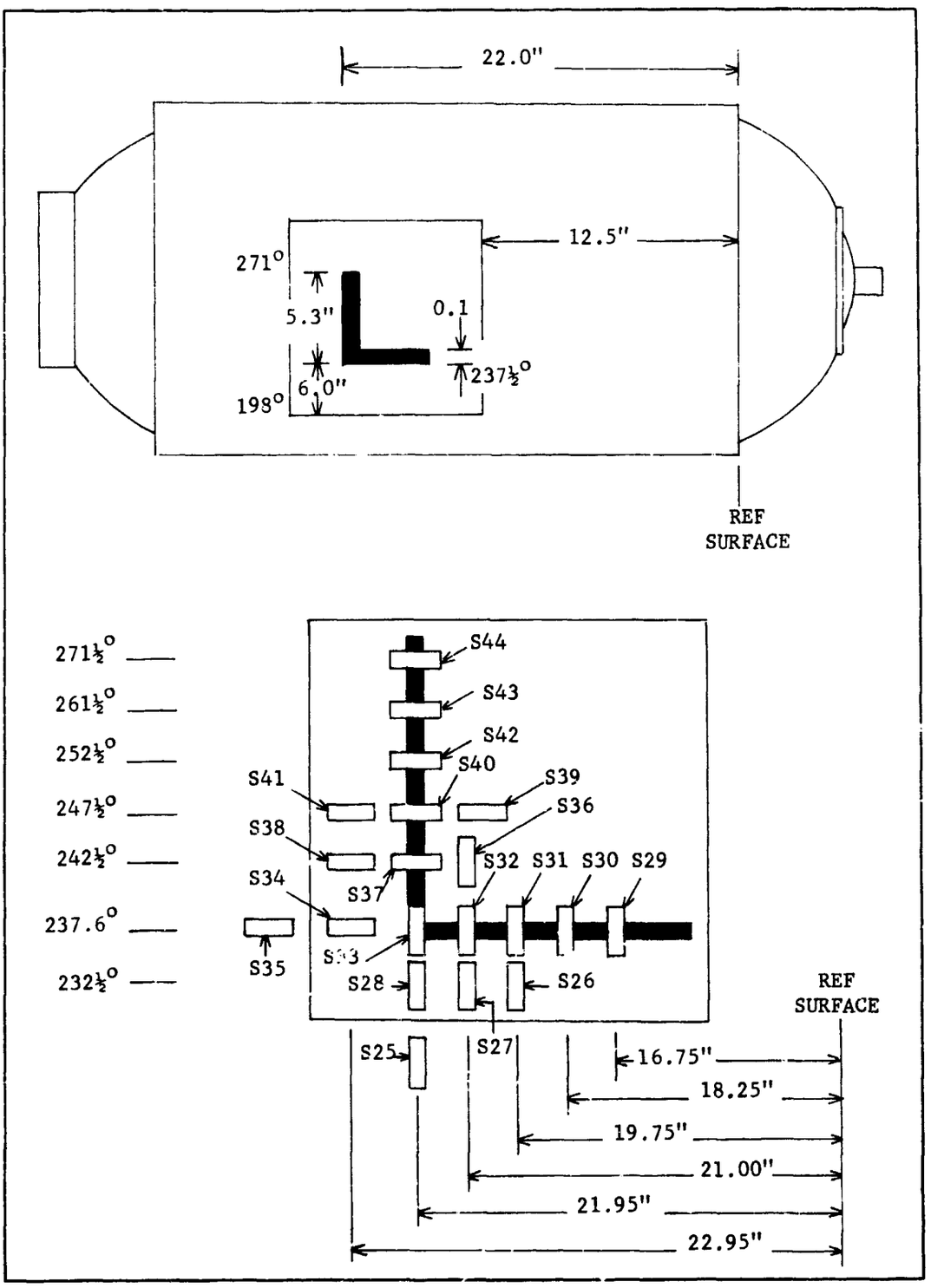


FIGURE 97 - STRAIN GAGE LOCATIONS X248 S/N NPP-453 (A6) DEFECT NO. 2

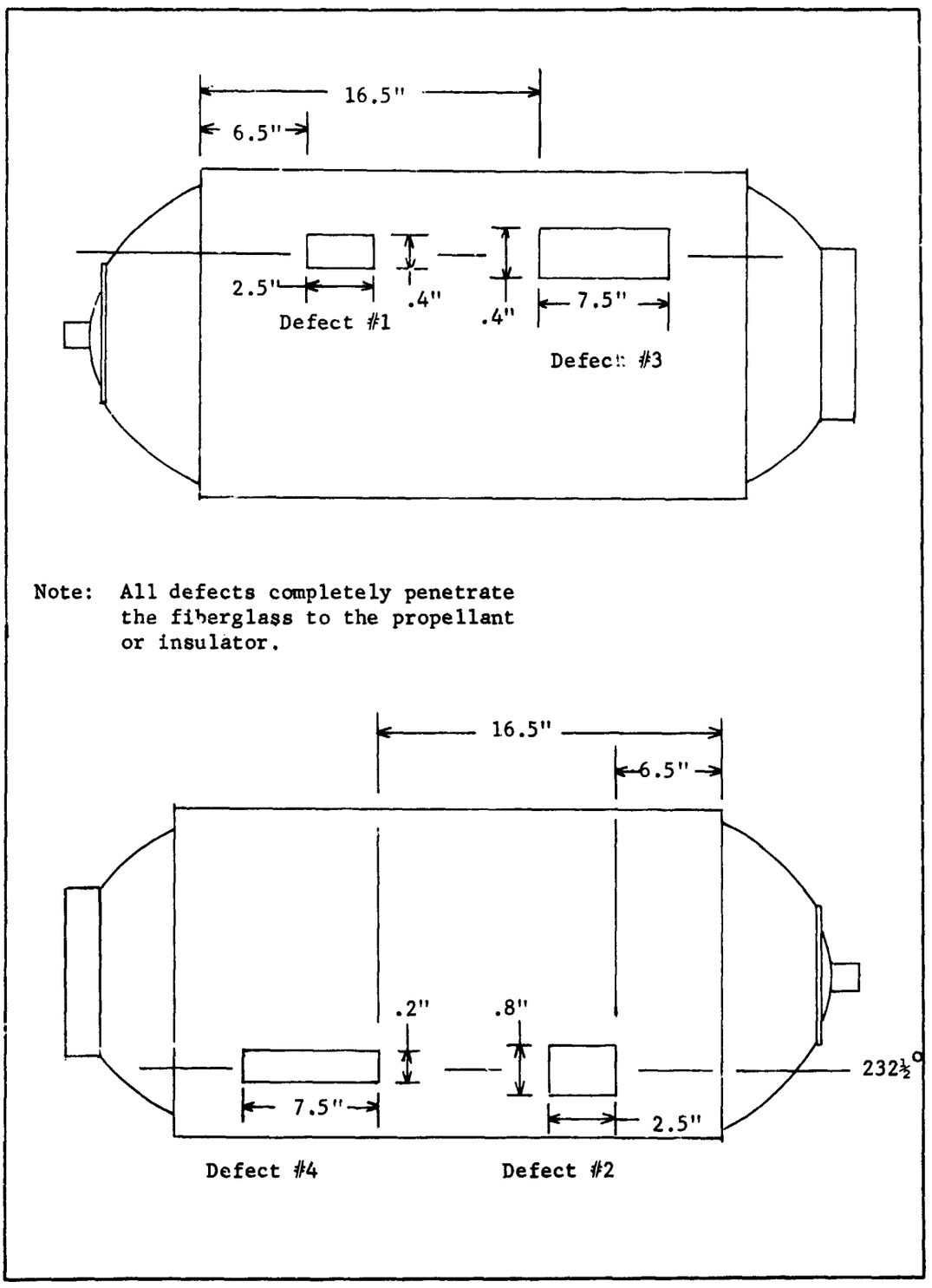


FIGURE 98 - DEFECT LOCATIONS X248 S/N Y-195 (A10)

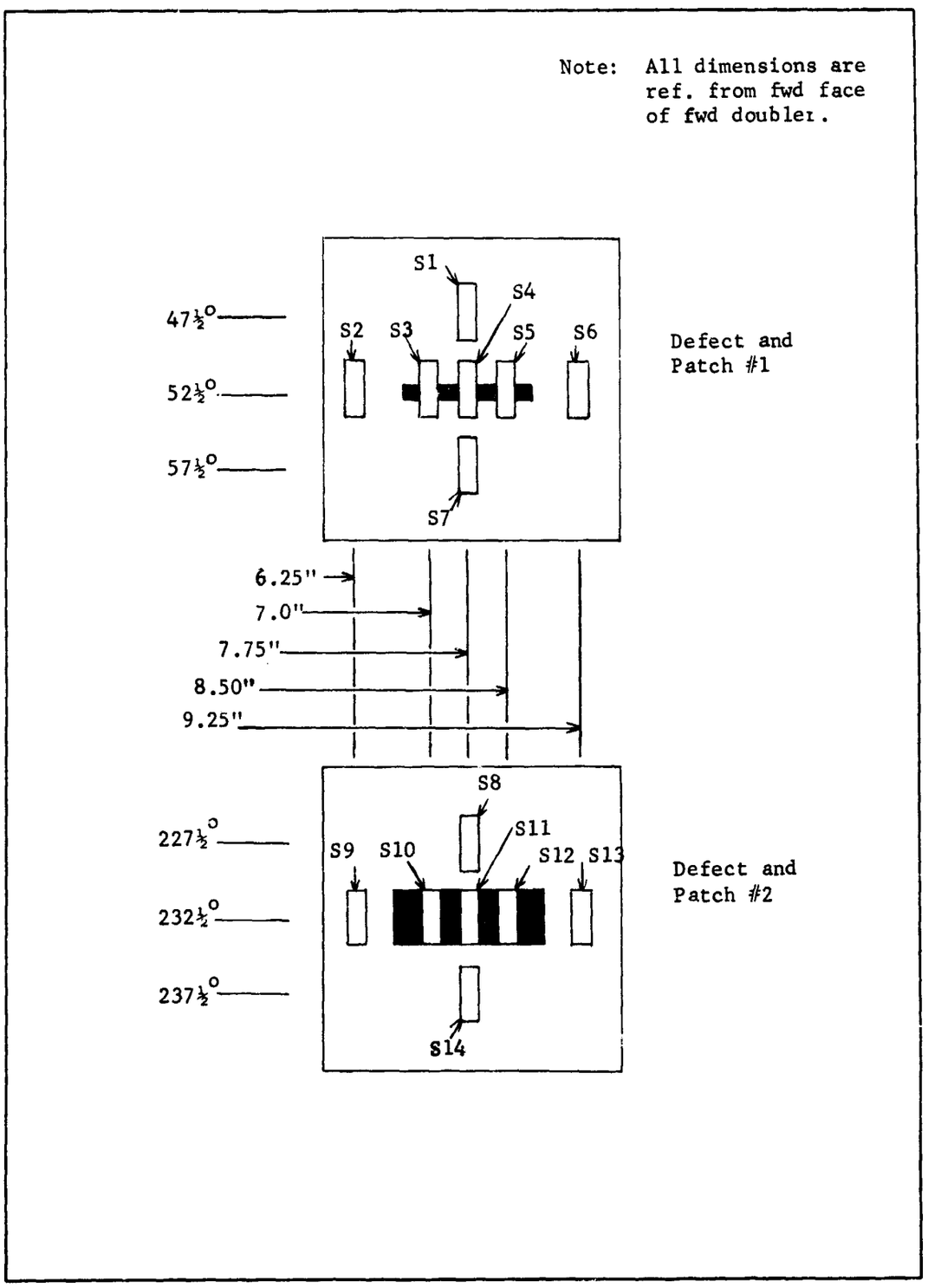


FIGURE 99 - STRAIN GAGE LOCATIONS X248 S/N Y-195 (A10)

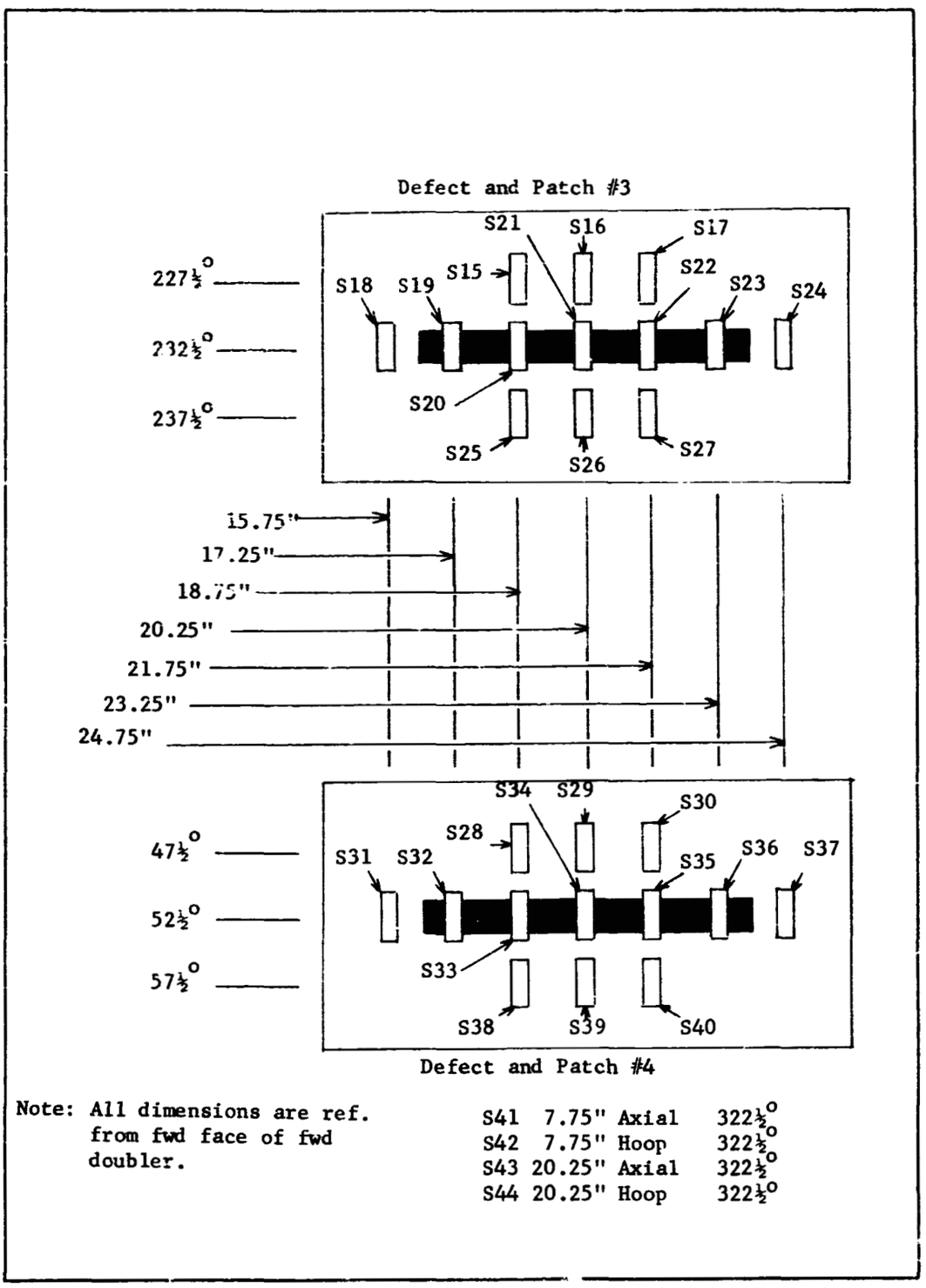


FIGURE 100 - STRAIN GAGE LOCATIONS X248 S/N Y-195(A10)

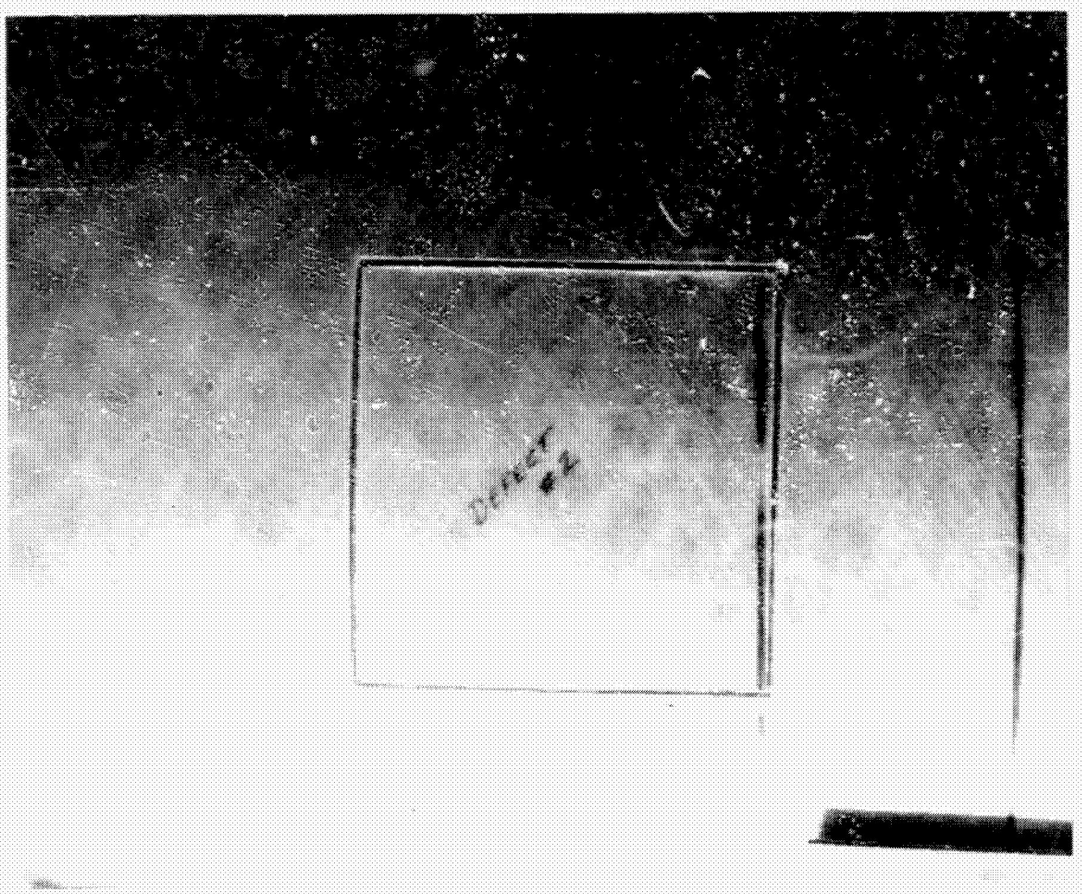
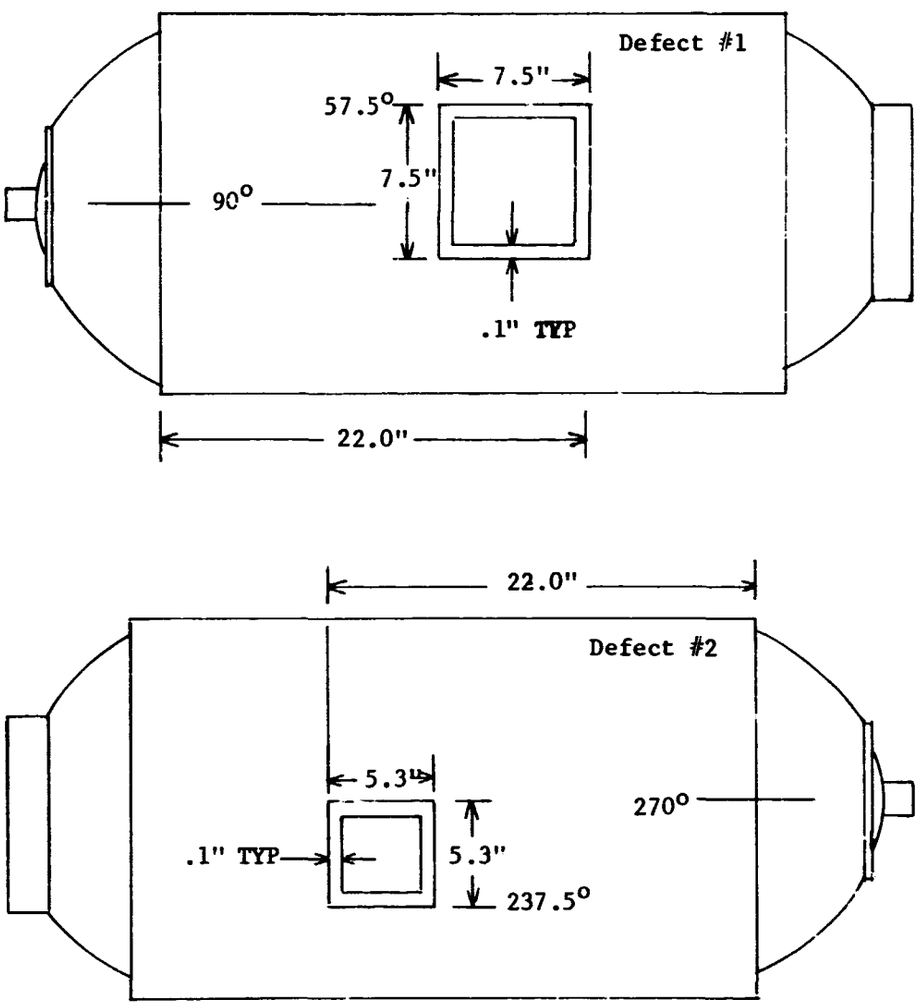


FIGURE 101 - DEFECT NO. 2 MACHINED IN X248 A6 S/N NPP- 463

G-2335



Note: Both defects completely penetrate the fiberglass to the insulator.

FIGURE 102 - DEFECT LOCATIONS X248 S/N NPP-463(A6)

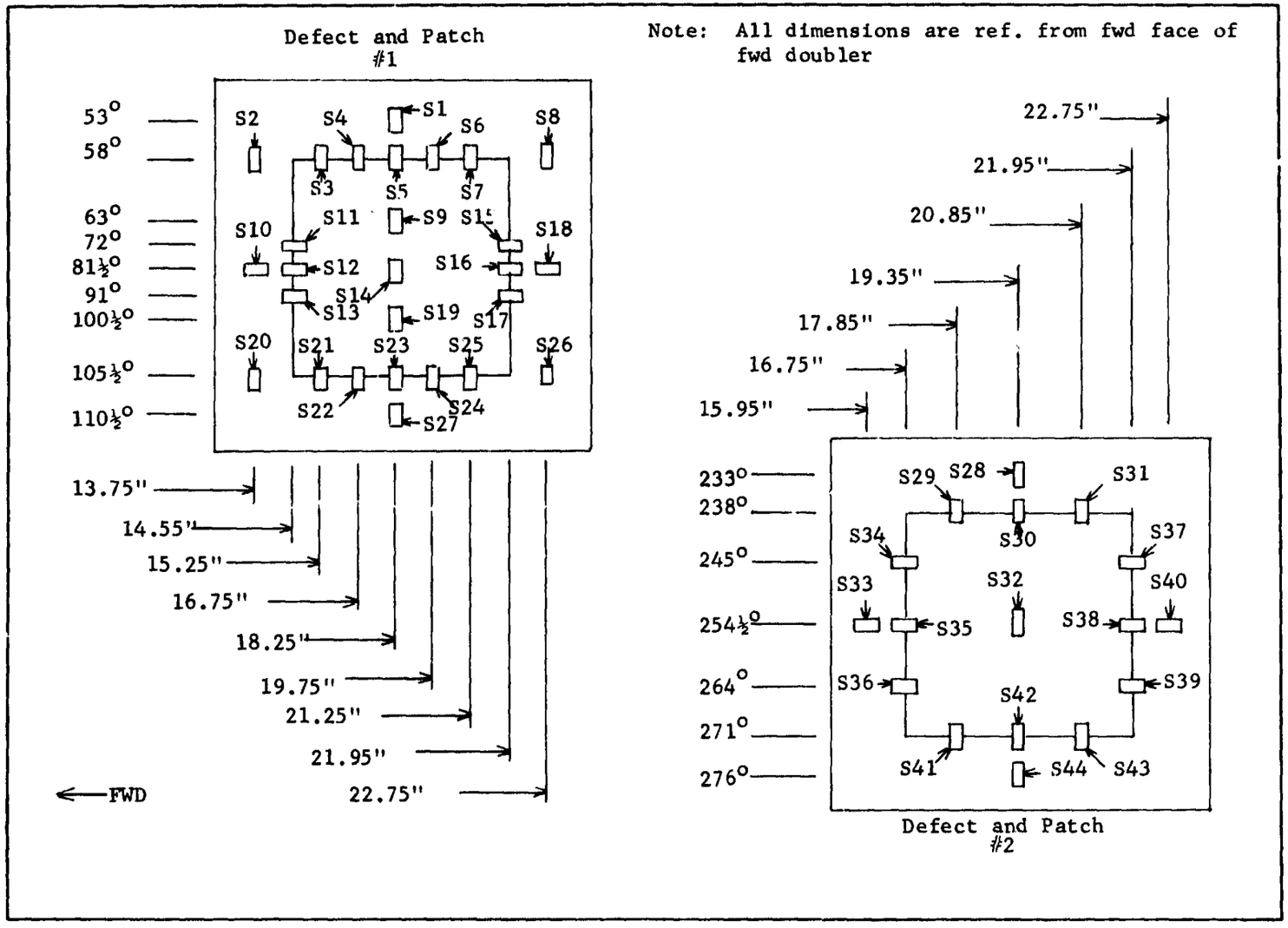


FIGURE 103 - STRAIN GAGE LOCATIONS X248 S/N NPP-463 (A6)

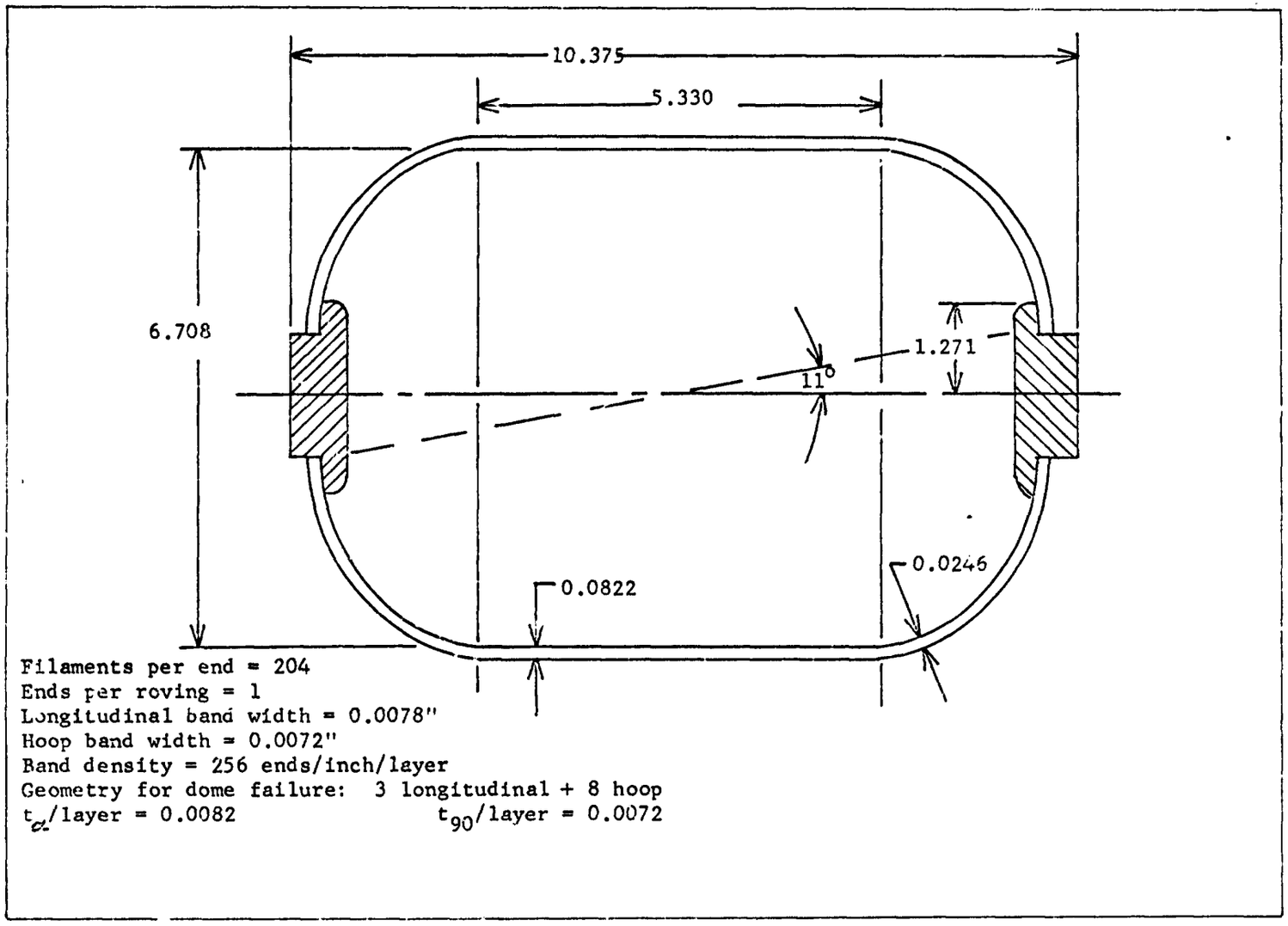


FIGURE 104 - WINDING GEOMETRY FOR SINGLE CIRCUIT PLANAR PATH OF 6-INCH BOTTLES

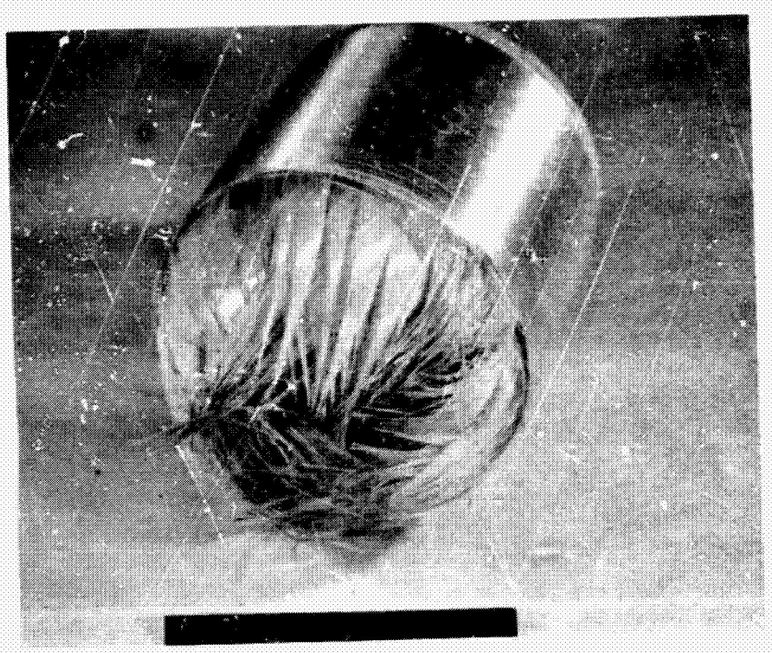


FIGURE 105 - FAILURE OF UNDEFECTED BOTTLE

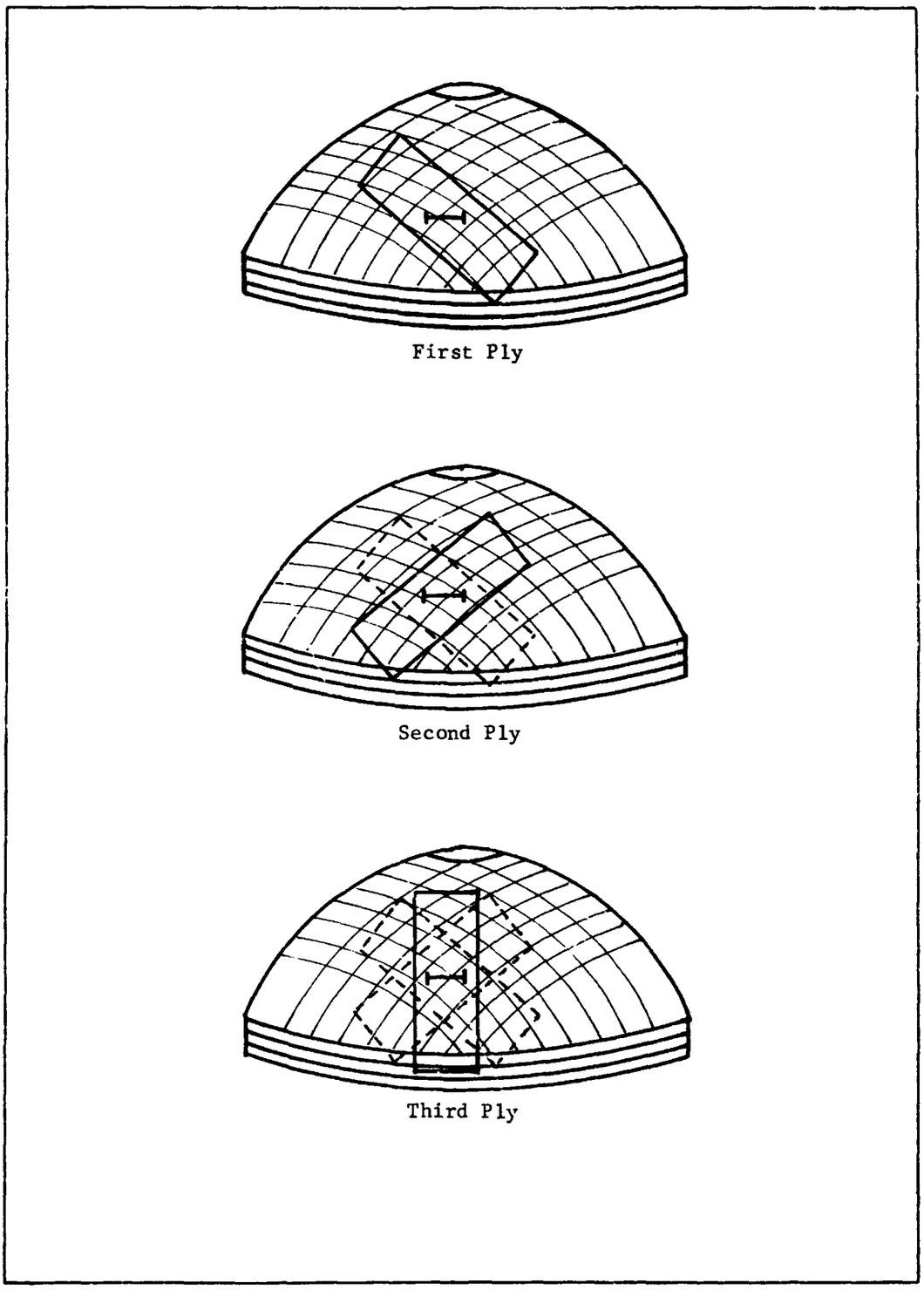


FIGURE 106 - ORIENTATION OF GLASS CLOTH PLIES ON DOMES OF 6-INCH BOTTLES

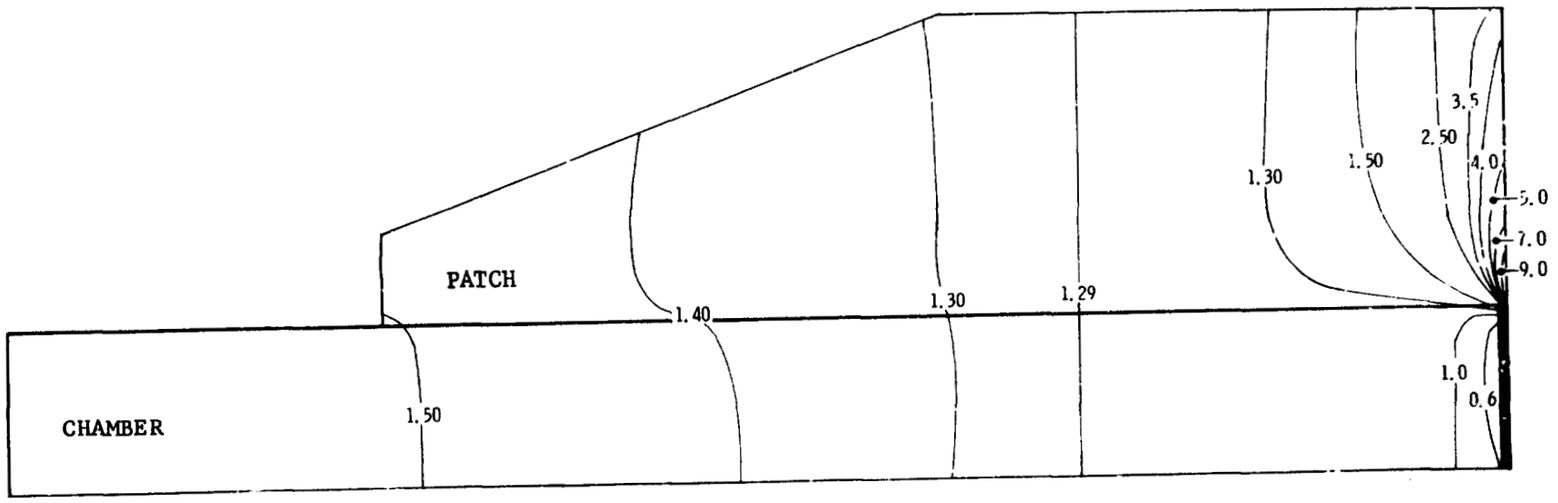


FIGURE 107 - HOOP ISOSTRAIN PATTERN (X 10^{-2}) FOR FOUR-PLY REPAIR OF 0.10-IN.-WIDE DEFECT

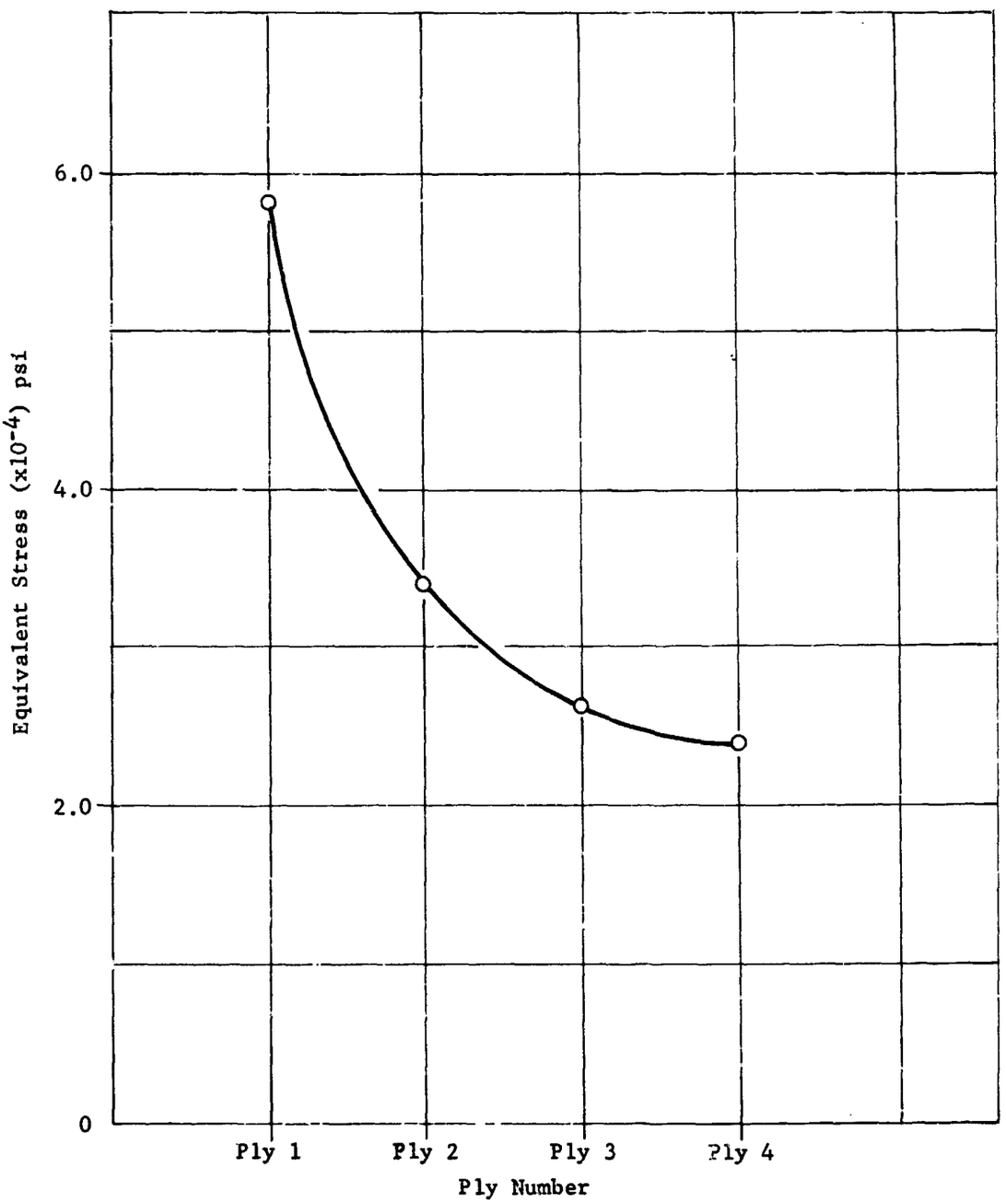


FIGURE 108 - AVERAGE EQUIVALENT STRESS ABOVE DEFECT - CONDITION 1

Adhesive	.04	.04	.05	.09	.13	.14	.16
Glass	.76	.77	.94	1.64	2.42	2.65	2.87
Cloth	.76	.77	.94	1.63	2.42	2.78	2.82
Bond Layer	.04	.04	.06	.12	.16	.17	.18
Glass	.76	.77	.92	1.56	2.49	2.92	3.08
Cloth	.76	.77	.91	1.54	2.51	3.07	3.12
Bond Layer	.04	.04	.07	.19	.26	.24	.22
Glass	.76	.77	.87	1.38	2.58	3.51	3.78
Cloth	.76	.77	.86	1.33	2.58	3.75	3.96
Bond Layer	.04	.04	.08	.27	.47	.45	.30
Glass	.76	.76	.80	1.05	2.4	5.11	5.33
Cloth	.76	.76	.79	.99	2.29	5.95	5.62
Bond Layer	.04	.04	.08	.30	1.04	.91	.33
	8.08	8.07	7.83	6.74	4.77		
Fiberglass	3.67	3.67	3.55	3.04	2.03		
Chamber	1.83	1.83	1.77	1.53	1.25		
	8.08	8.07	7.81	6.65	4.15		
	1.26	1.26	1.22	1.03	.66		
	1.26	1.26	1.22	1.03	.66		

FIGURE 109 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 2

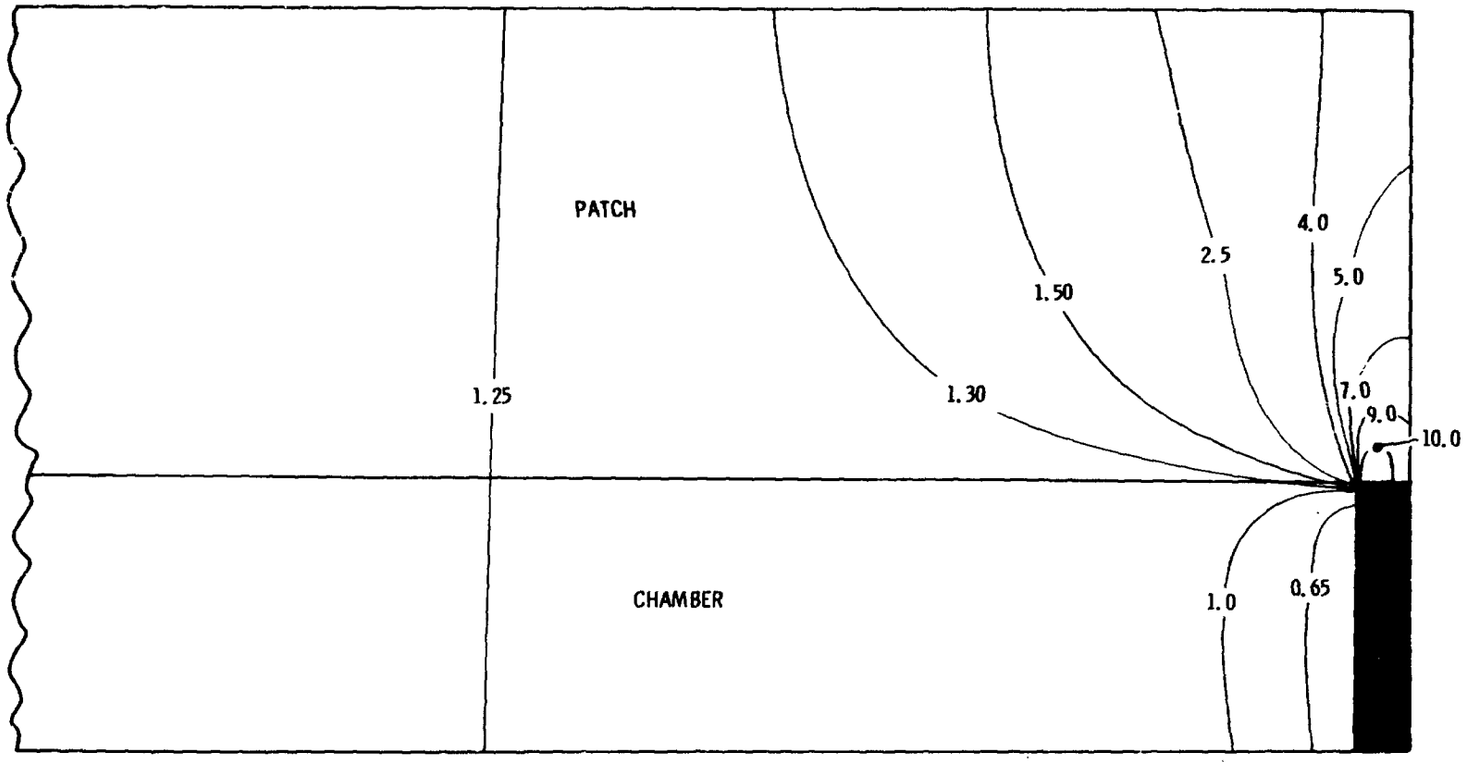


FIGURE 110 - HOOP ISOSTRAIN PATTERN ($X10^{-2}$) FOR FOUR-PLY REPAIR OF 0.20-IN.-WIDE DEFECT

Adhesive	.04	.04	.06	.12	.17	.17	.20
Glass	.72	.74	1.05	2.18	3.07	3.30	3.51
Cloth	.72	.74	1.04	2.17	3.09	3.42	3.42
Bond Layer	.04	.04	.07	.16	.19	.20	.20
Glass	.72	.73	1.00	2.11	3.24	3.53	3.60
Cloth	.72	.73	.99	2.09	3.30	3.64	3.57
Bond Layer	.04	.04	.10	.26	.28	.23	.21
Glass	.72	.73	.91	1.95	3.65	3.90	3.89
Cloth	.71	.73	.89	1.91	3.78	4.02	3.90
Bond Layer	.04	.04	.13	.41	.42	.26	.22
Glass	.71	.72	.79	1.57	4.59	4.39	4.15
Cloth	.71	.72	.76	1.48	4.91	4.42	4.16
Bond Layer	.04	.04	.12	.69	.61	.25	.22
	7.6	7.57	7.13	5.21			
Fiberglass	3.45	3.44	3.23	2.28			
Chamber	1.72	1.71	1.61	1.28			
	7.6	7.56	7.10	4.81			
	1.18	1.18	1.10	.76			
	1.18	1.18	1.10	.76			

FIGURE 111 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 3

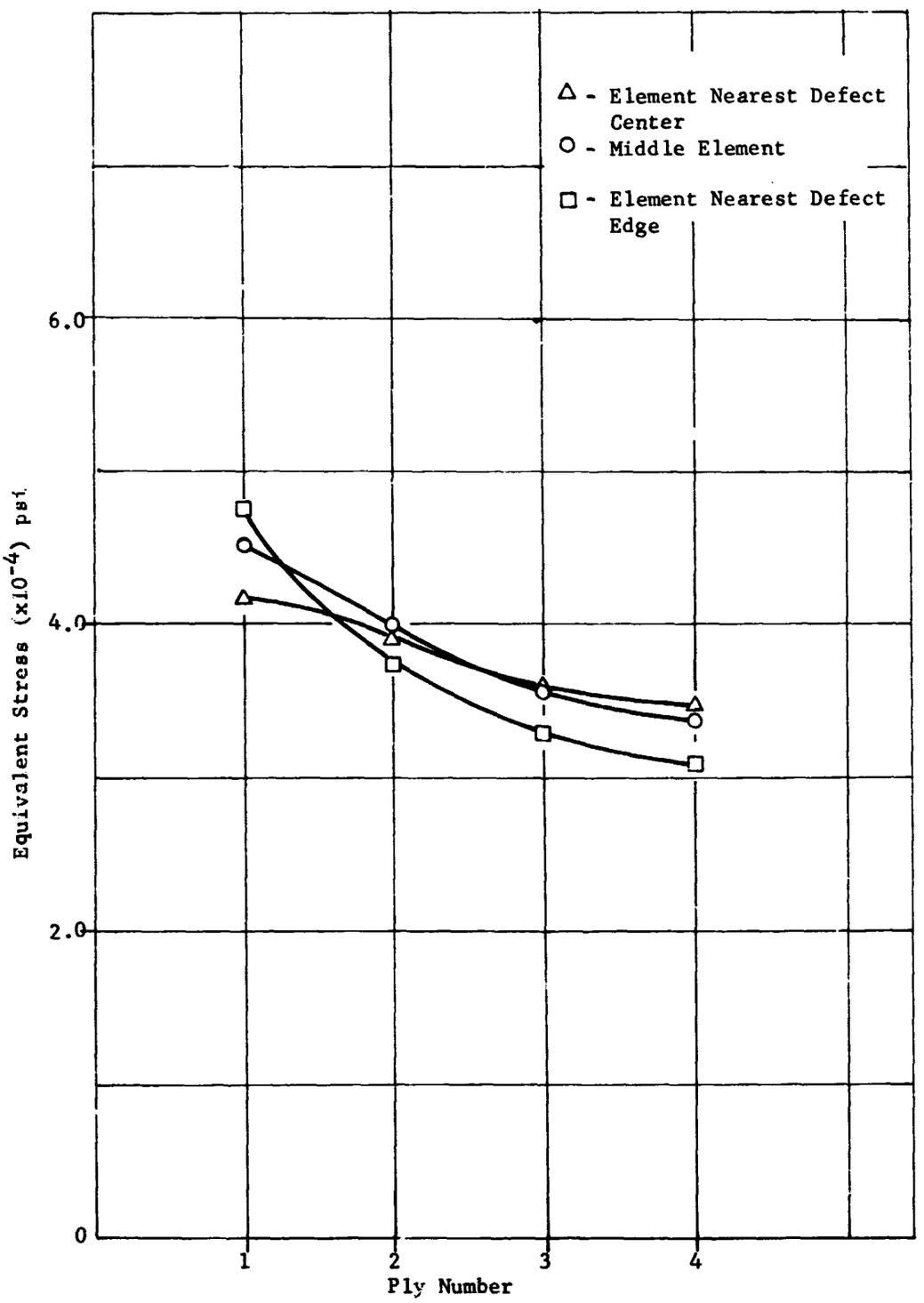


FIGURE 112 - COMPARISON OF THE AVERAGE EQUIVALENT STRESS PER PLY - CONDITION 3

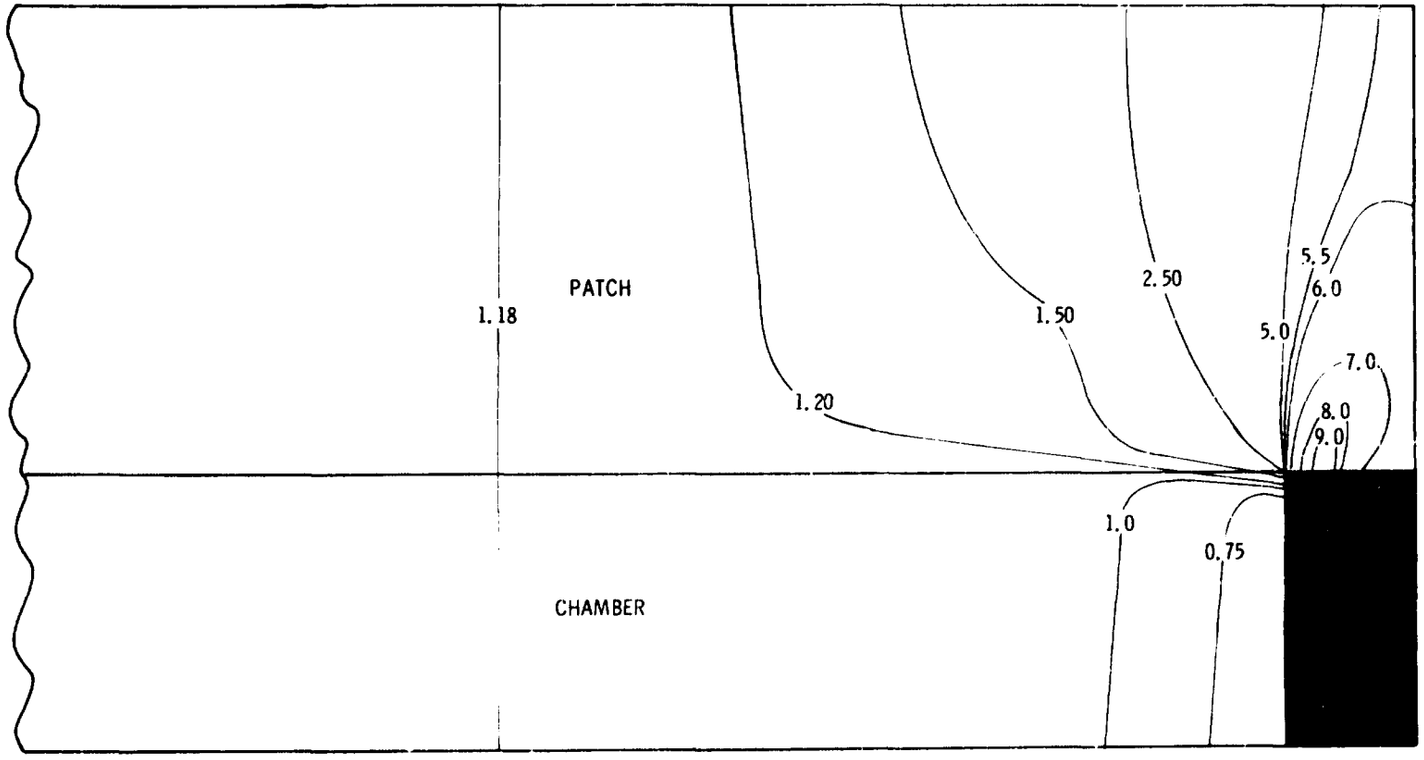


FIGURE 113 - HOOP ISOSTRAIN PATTERN (X 10^{-2}) FOR FOUR-PLY REPAIR OF 0.50-IN.-WIDE DEFECT

Adhesive	.04	.04	.05	.08	.13	.15	.17
Glass	.78	.78	.86	1.38	2.36	2.89	3.11
Cloth	.78	.78	.86	1.37	2.35	2.98	3.13
Bond Layer	.04	.04	.05	.11	.19	.21	.21
Glass	.78	.78	.84	1.26	2.31	3.3	3.67
Cloth	.78	.78	.83	1.23	2.27	3.46	3.89
Bond Layer	.04	.04	.05	.17	.39	.44	.33
Glass	.78	.78	.81	1.02	1.93	4.09	5.78
Cloth	.78	.78	.80	.97	1.79	4.06	6.81
Bond Layer	.04	.04	.05	.20	.69	1.46	1.12
	8.32	8.32	8.23	7.64	6.26	4.91	
Fiberglass	3.78	3.78	3.74	3.46	2.74	1.80	
Chamber	1.88	1.88	1.86	1.73	1.48	1.3	
	8.32	8.32	8.22	7.58	5.88	3.4	
	1.3	1.30	1.28	1.18	.91	.68	
	1.3	1.30	1.28	1.18	.90	.72	

FIGURE 114 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 4

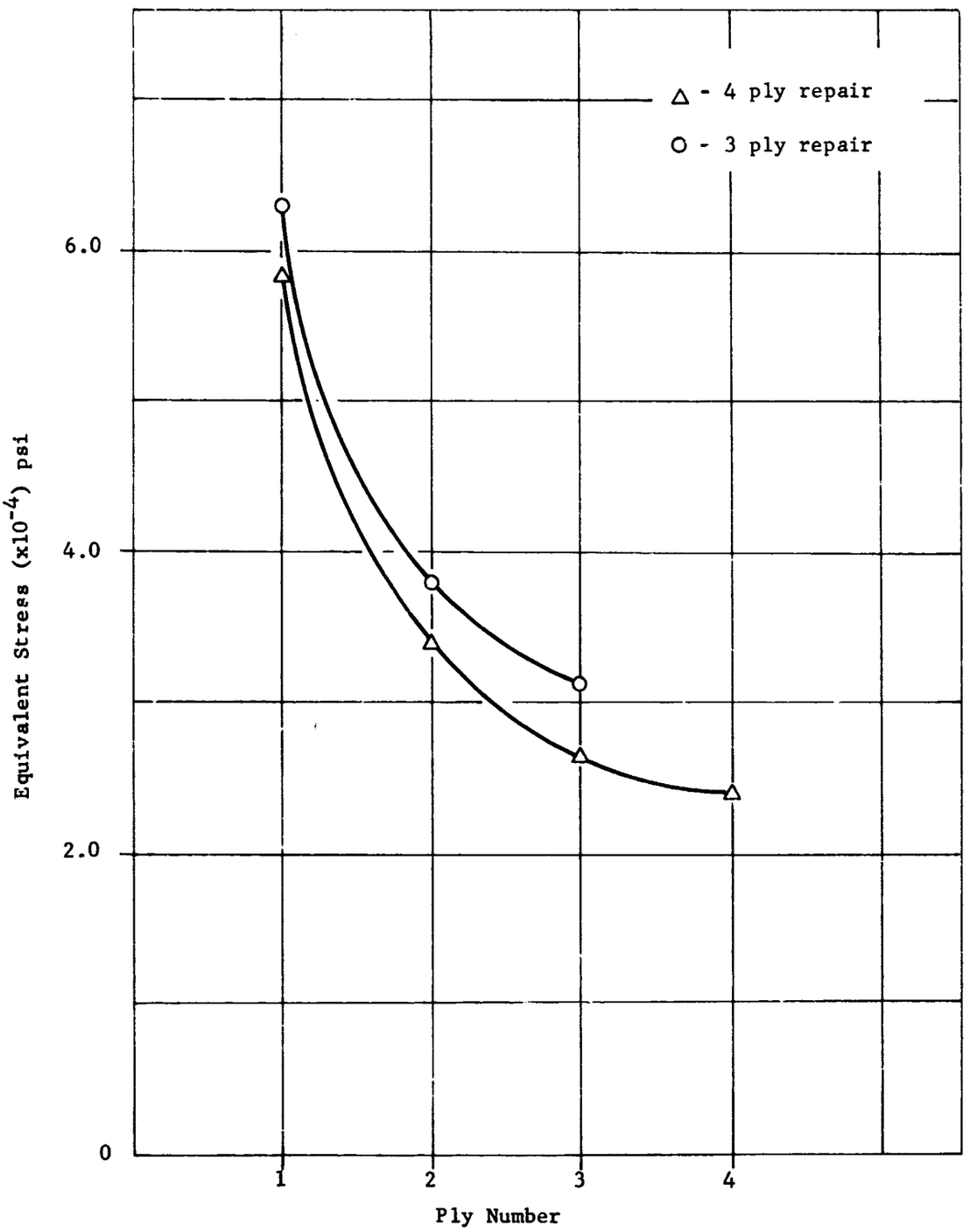


FIGURE 115 - AVERAGE EQUIVALENT STRESSES FOR 3- AND 4-PLY REPAIRS - CONDITION 4 (STRESSES MEASURED AT DEFECT CENTER)

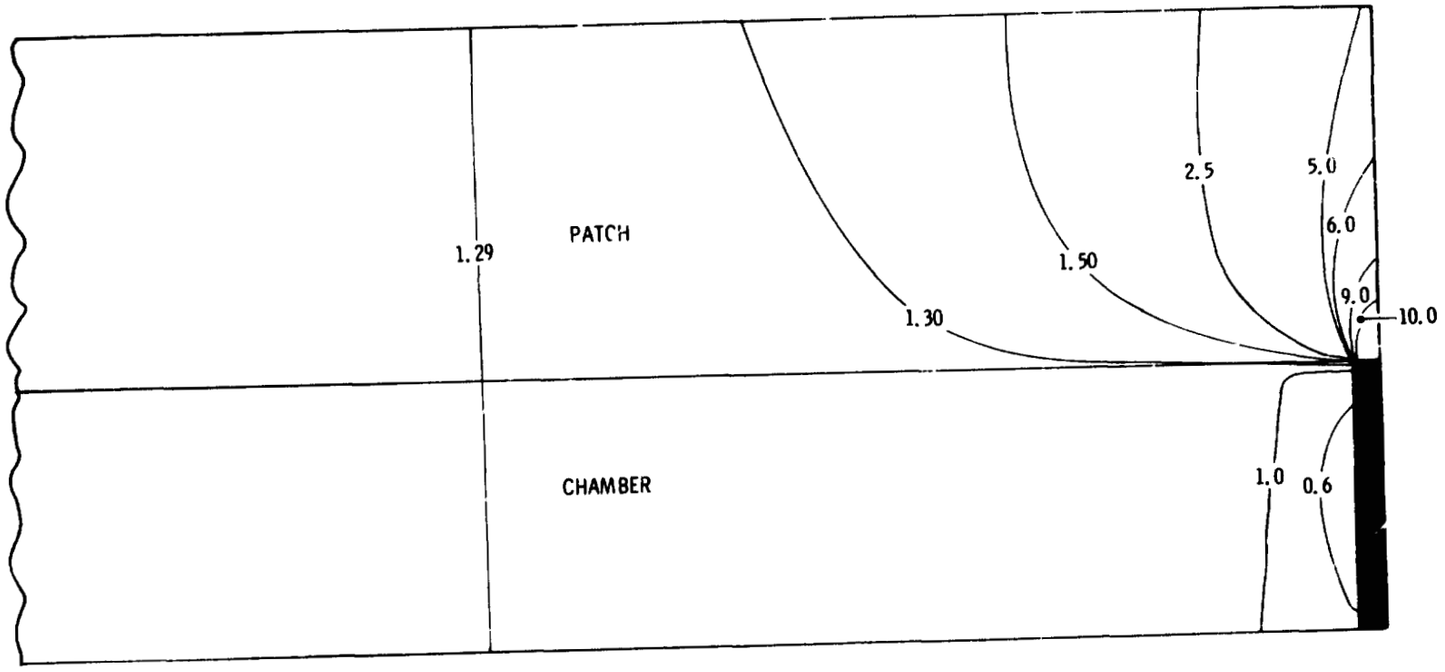


FIGURE 116 - HOOP ISOSTRAIN PATTERN (X 10^{-2}) FOR THREE-PLY REPAIR OF 0.10-IN.-WIDE DEFECT

Adhesive	.03	.03	.04	.07	.10	.11	.13
Glass	.54	.54	.68	1.23	1.88	2.19	2.23
Cloth	.54	.54	.69	1.24	1.88	2.18	2.25
Bond Layer	.03	.03	.04	.09	.13	.13	.14
Glass	.54	.54	.67	1.17	1.92	2.33	2.46
Cloth	.54	.54	.66	1.16	1.93	2.43	2.51
Bond Layer	.03	.03	.05	.15	.22	.20	.18
Glass	.54	.54	.63	1.03	1.94	2.82	3.15
Cloth	.54	.54	.62	1.00	1.92	2.99	3.37
Bond Layer	.03	.03	.06	.20	.40	.43	.30
Glass	.54	.54	.58	.79	1.64	3.66	5.23
Cloth	.54	.54	.57	.74	1.54	3.63	6.21
Bond Layer	.03	.03	.06	.23	.69	1.39	1.05
	5.71	5.71	5.58	5.10	4.35	3.8	
Fiberglass	2.60	2.60	2.54	2.31	1.95	1.44	
Chamber	5.71	5.71	5.57	5.02	3.94	2.29	
	1.29	1.29	1.26	1.14	.89	.65	
	5.71	5.71	5.56	4.98	3.77	2.51	
	.89	.89	.87	.77	.58	.62	

FIGURE 117 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 5

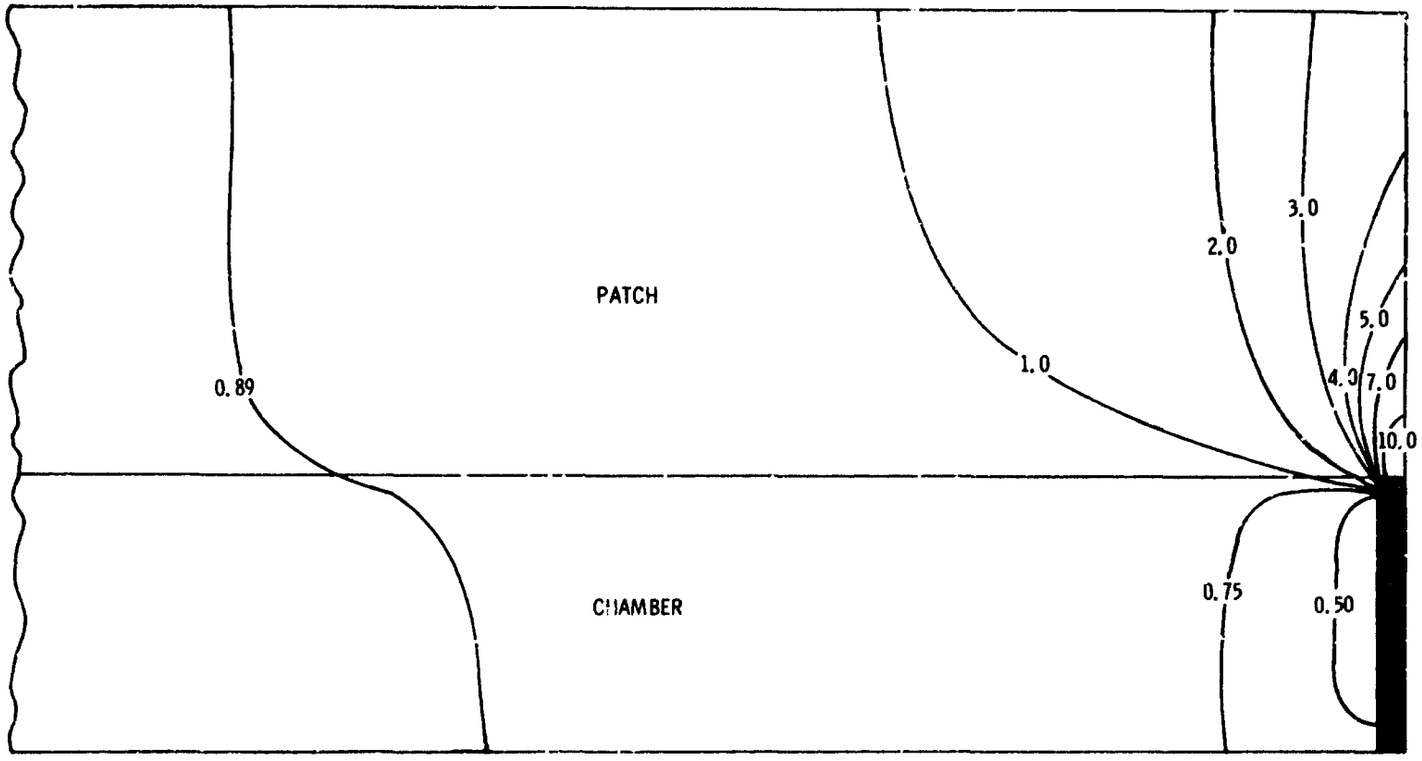


FIGURE 118 - HOOP ISOSTRAIN PATTERN (X 10^{-2}) FOR FOUR-PLY REPAIR OF 0.10-IN.-WIDE DEFECT ON A6 CHAMBER

Adhesive	.04	.04	.05	.08	.11	.11	.13
Glass	.78	.80	.97	1.51	2.01	2.15	2.30
Cloth	.78	.80	.97	1.50	2.02	2.23	2.24
Bond Layer	.04	.04	.06	.10	.12	.13	.14
Glass	.78	.79	.94	1.45	2.09	2.37	2.40
Cloth	.78	.79	.94	1.44	2.10	2.47	2.49
Bond Layer	.04	.04	.06	.14	.18	.18	.17
Glass	.78	.79	.89	1.30	2.16	2.86	3.12
Cloth	.78	.79	.88	1.28	2.15	3.02	3.26
Bond Layer	.04	.04	.07	.20	.34	.35	.28
Glass	.78	.78	.82	1.03	1.93	3.84	5.16
Cloth	.78	.78	.81	.99	1.84	3.87	5.99
Bond Layer	.04	.04	.07	.23	.63	1.18	.94
	8.25	8.22	7.97	7.06	5.59	4.3	
Fiberglass	3.75	3.73	3.62	3.19	2.46	1.66	
Chamber	1.87	1.86	1.80	1.60	1.32	1.13	
	8.25	8.22	7.95	7.00	5.30	3.23	
	1.27	1.28	1.24	1.09	.82	.66	
	1.29	1.28	1.24	1.09	.82	.70	

FIGURE 119 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 6

Adhesive	.05	.05	.06	.13	.13	.14	.14
Glass	.69	.70	.82	1.37	2.05	2.27	2.46
Cloth	.69	.70	.82	1.36	2.05	2.39	2.40
Bond Layer	.05	.05	.06	.12	.16	.16	.15
Glass	.69	.70	.80	1.29	2.10	2.53	2.66
Cloth	.69	.70	.80	1.27	2.11	2.66	2.71
Bond Layer	.05	.05	.07	.17	.25	.23	.19
Glass	.69	.70	.77	1.14	2.12	3.08	3.42
Cloth	.69	.70	.76	1.11	2.10	3.28	3.66
Bond Layer	.05	.05	.08	.23	.46	.50	.33
Glass	.69	.70	.72	.89	1.79	4.04	5.77
Cloth	.69	.69	.71	.85	1.68	4.05	6.89
Bond Layer	.05	.05	.08	.26	.79	1.61	1.17
	7.94	7.93	7.74	6.92	5.47	4.59	
Fiberglass	4.89	4.88	4.78	4.34	3.54	2.69	
Chamber	3.71	3.71	3.65	3.40	2.94	2.58	
	7.94	7.93	7.73	6.85	5.06	2.91	
	3.47	3.46	3.43	3.31	3.04	3.05	
	3.47	3.46	3.43	3.31	3.04	3.14	

FIGURE 120 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 7

Adhesive	.03	.03	.05	.08	.09	.09	.10
Glass	.53	.55	.87	1.54	1.61	1.69	1.74
Cloth	.53	.55	.87	1.55	1.63	1.69	1.68
Bond Layer	.03	.03	.06	.09	.09	.09	.09
Glass	.53	.55	.84	1.61	1.65	1.67	1.67
Cloth	.53	.55	.83	1.63	1.68	1.65	1.63
Bond Layer	.03	.03	.09	.11	.09	.09	.09
Glass	.53	.54	.77	1.78	1.68	1.63	1.61
Cloth	.53	.54	.75	1.82	1.70	1.62	1.56
Bond Layer	.03	.03	.17				
Glass	.52	.54	.60	.30	1.75	4.97	7.32
Cloth	.52	.53	.58	.35	1.62	4.76	8.15
Bond Layer	.03	.03	.11	.13	.47	1.35	1.15
	5.58	5.56	5.28	4.49	4.41	4.16	
Fiberglass	2.54	2.53	2.40	2.05	1.94	1.52	
Chamber	5.58	5.56	5.26	4.51	3.98	2.51	
	1.26	1.26	1.19	1.02	.88	.71	
	5.58	5.55	5.25	4.51	3.82	2.81	
	.87	.87	.82	.70	.60	.71	

FIGURE 121 - EQUIVALENT STRESS ($x10^{-4}$) PSI IN DEFECT AREA - CONDITION 8

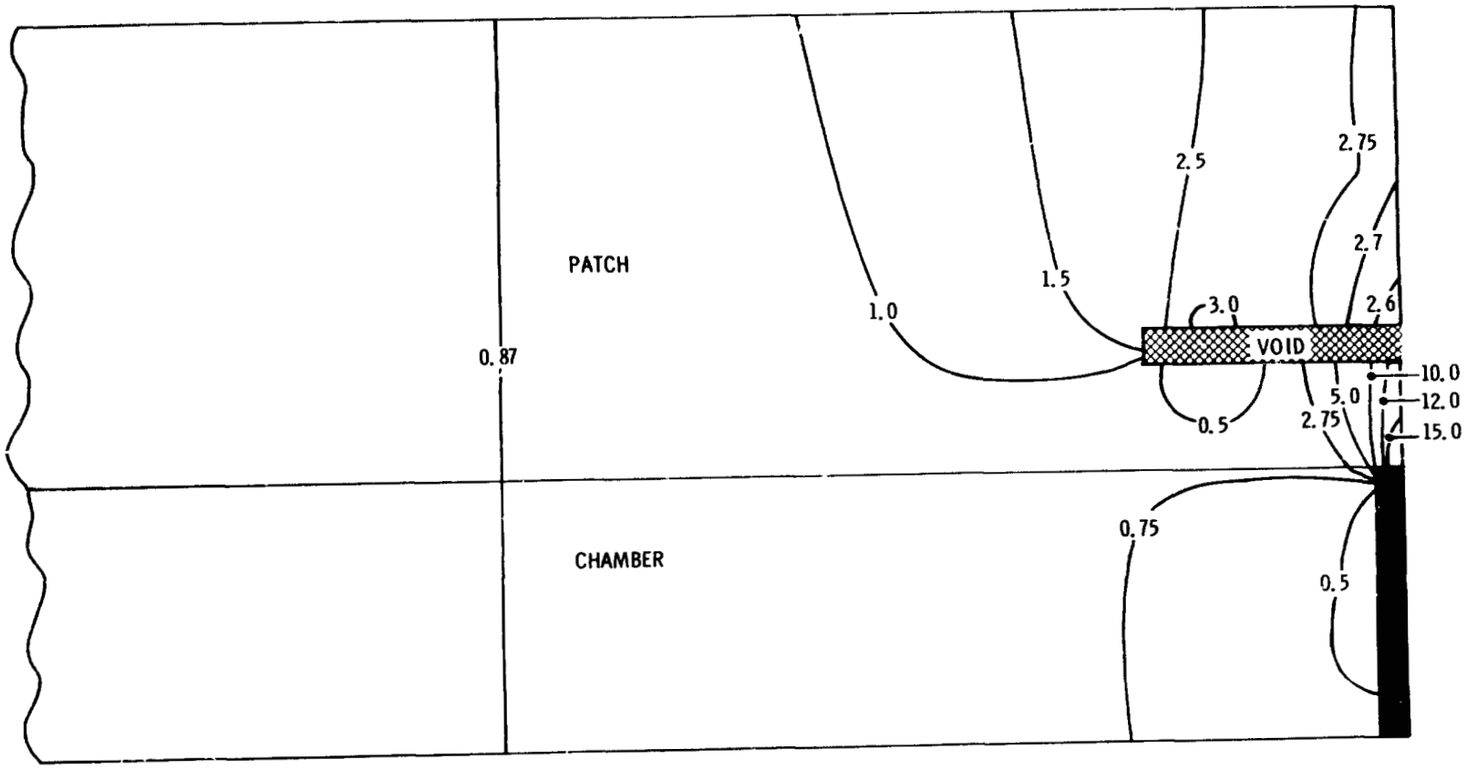
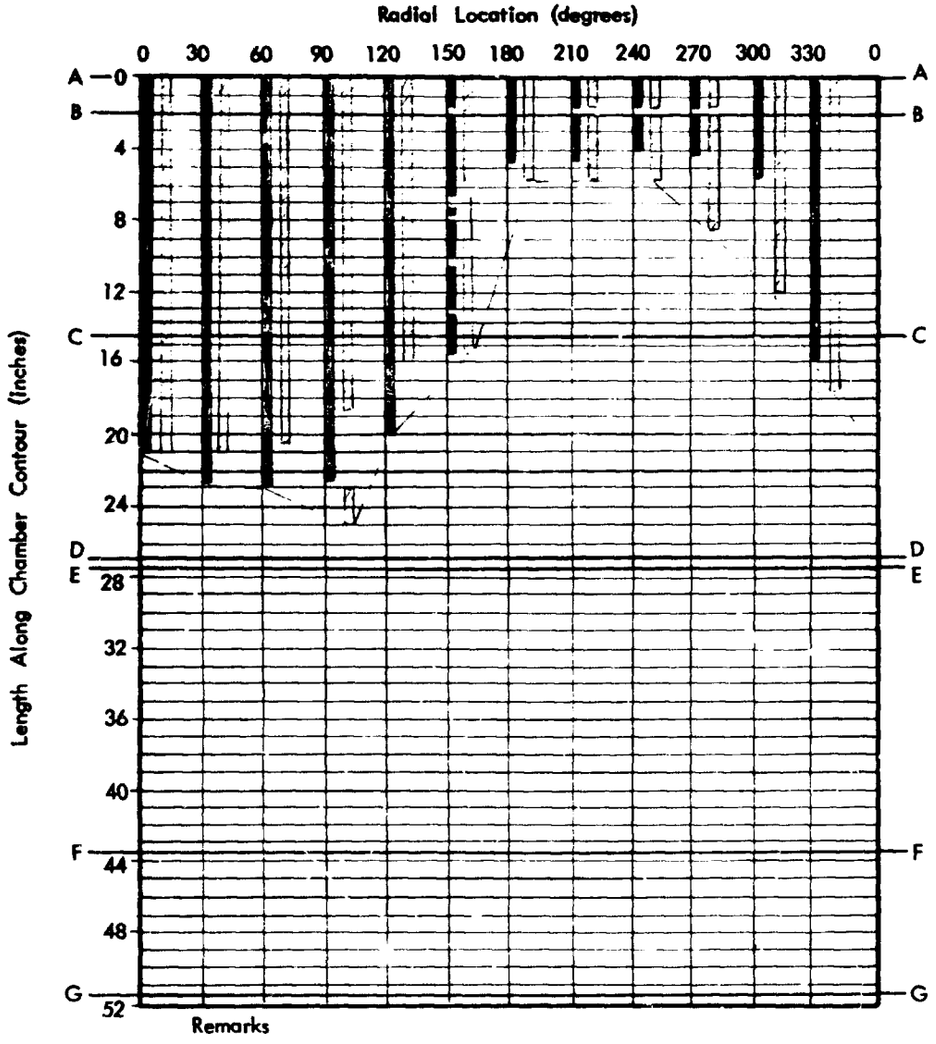
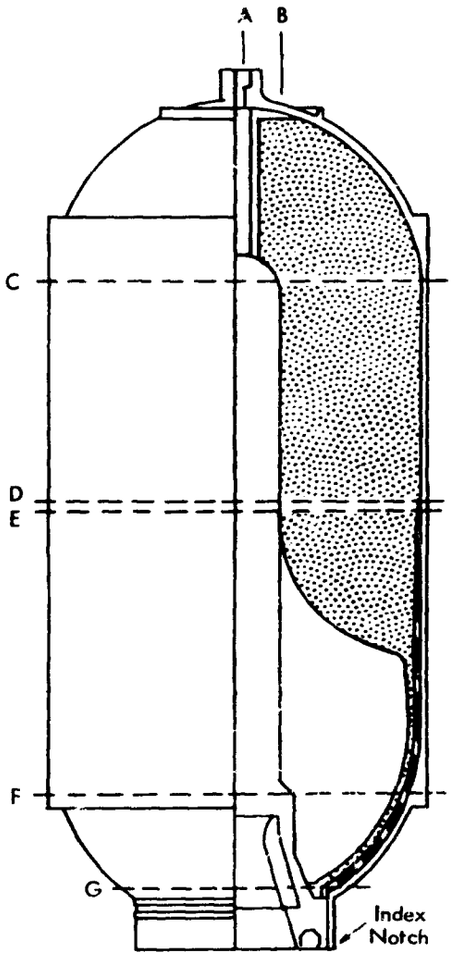


FIGURE 122 - HOOP ISOSTRAIN PATTERN (X 10^{-2}) FOR PLY REPAIR OF 0.100 IN. WIDE DEFECT WITH 1.0 IN. LONG VOID

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-400
Date Inspected	----





Incoming inspection 10/12/66

Post acceleration inspection 7/12/67

FIGURE 123

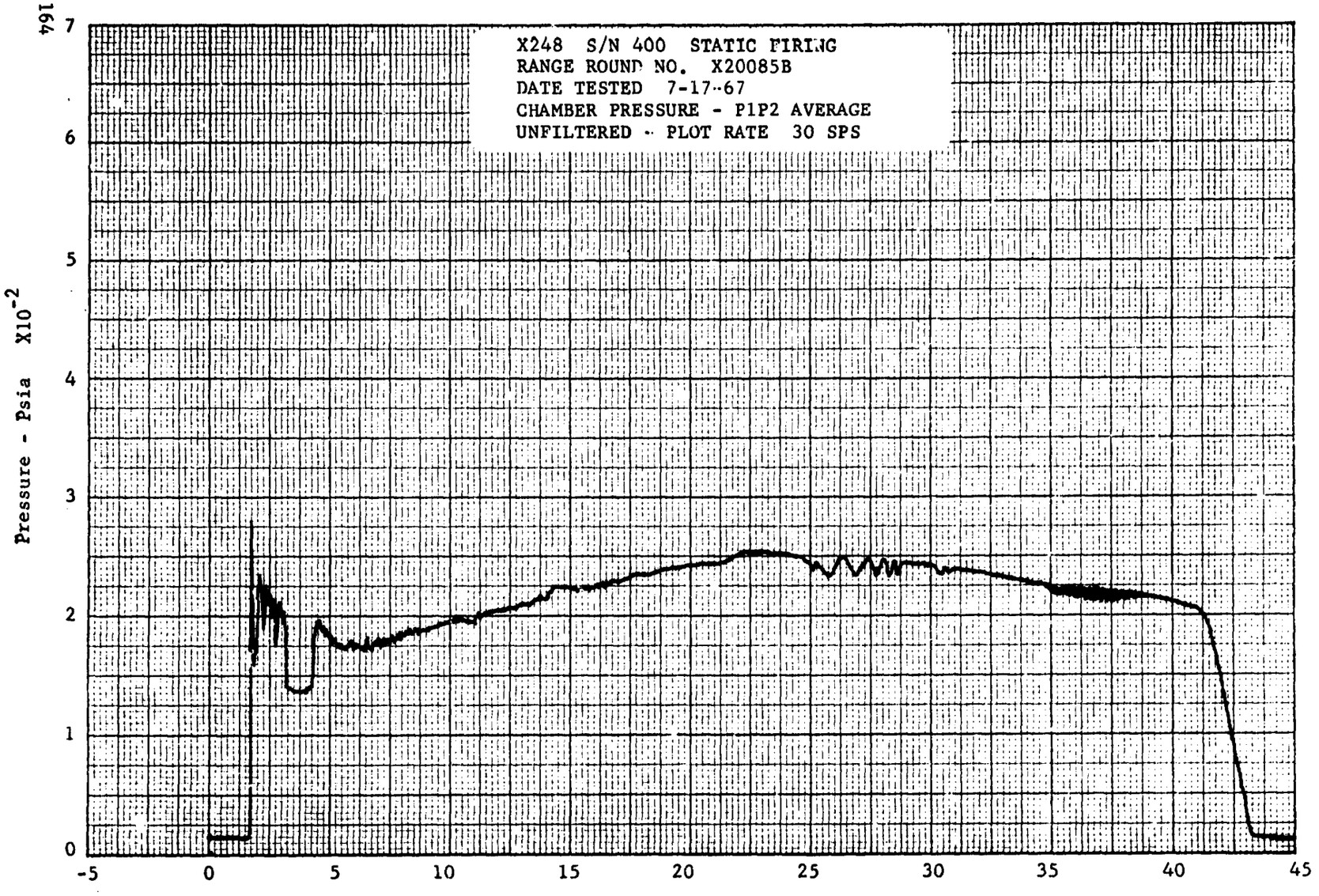

X248 S/N 400 STATIC FIRING
RANGE ROUND NO. X20085B
DATE TESTED 7-17-67
CHAMBER PRESSURE - P1P2 AVERAGE
UNFILTERED - PLOT RATE 30 SPS
Pressure - Psia X10-2
0
1
2
3
4
5
6
7
-5
0
5
10
15
20
25
30
35
40
45
Time - Seconds

FIGURE 124

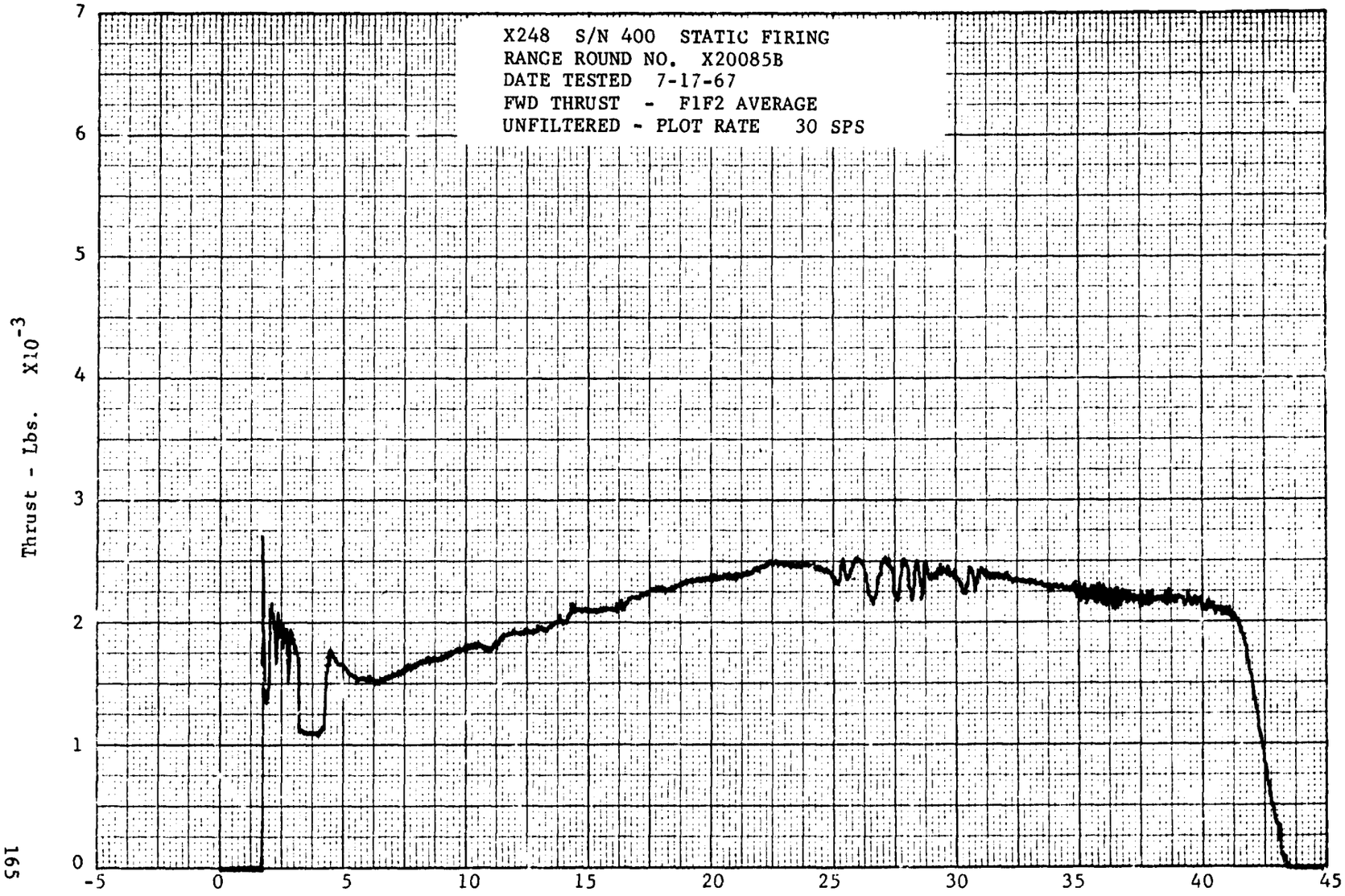
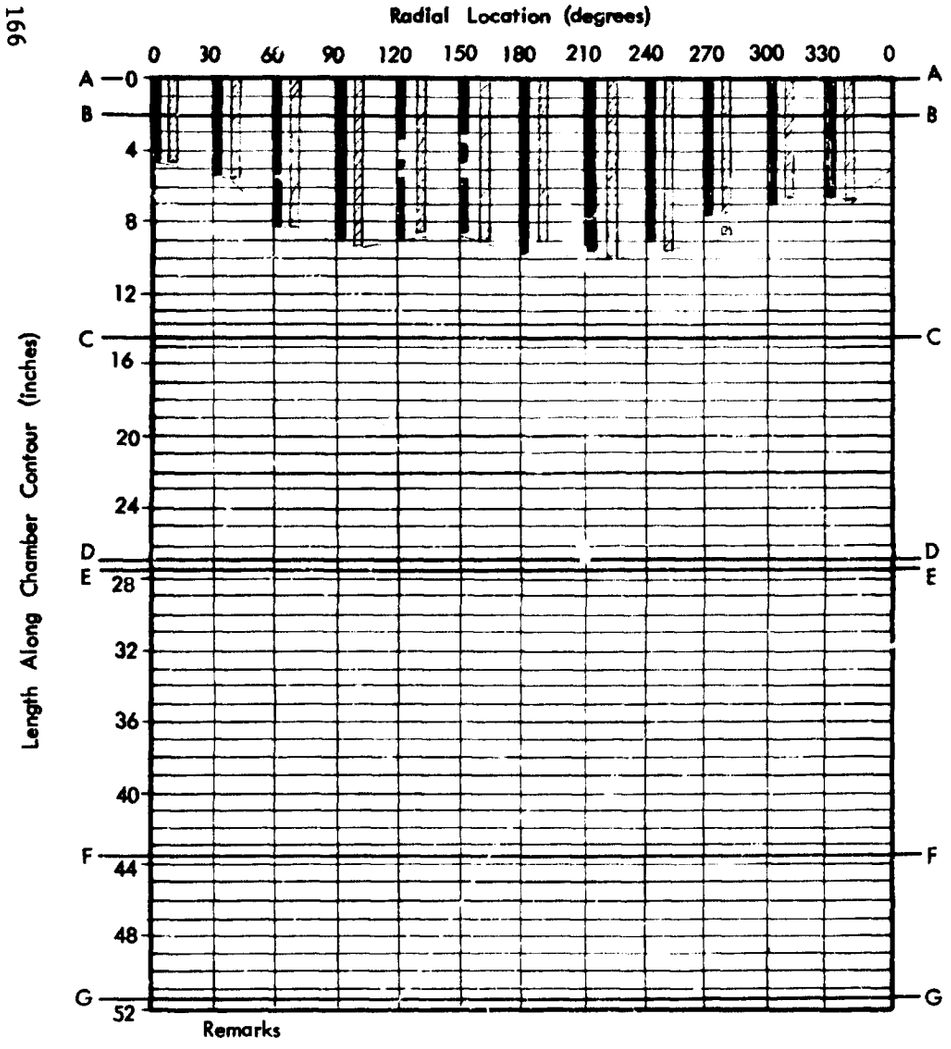
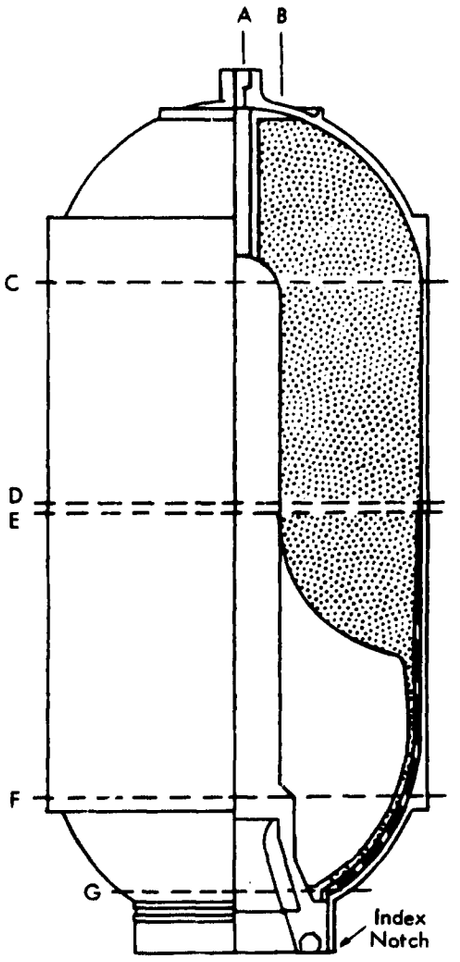

X248 S/N 400 STATIC FIRING
RANGE ROUND NO. X20085B
DATE TESTED 7-17-67
FWD THRUST - F1F2 AVERAGE
UNFILTERED - PLOT RATE 30 SPS
Thrust - Lbs. X10-3
0
1
2
3
4
5
6
7
-5
0
5
10
15
20
25
30
35
40
45
Time - Seconds

FIGURE 125

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-446
Date Inspected	----





Incoming inspection 10/15/66

Post acceleration inspection 7/17/67

FIGURE 126

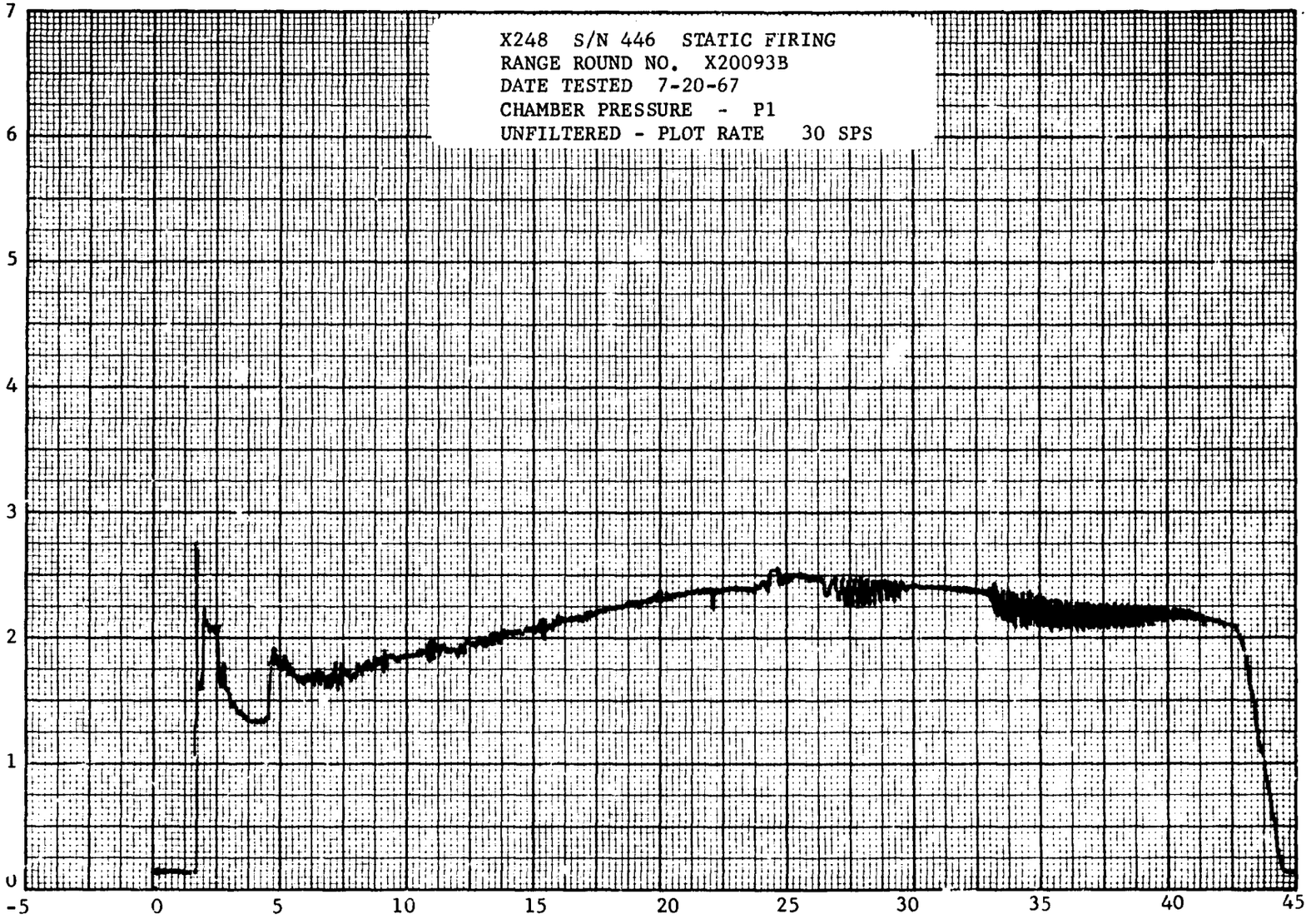


FIGURE 127

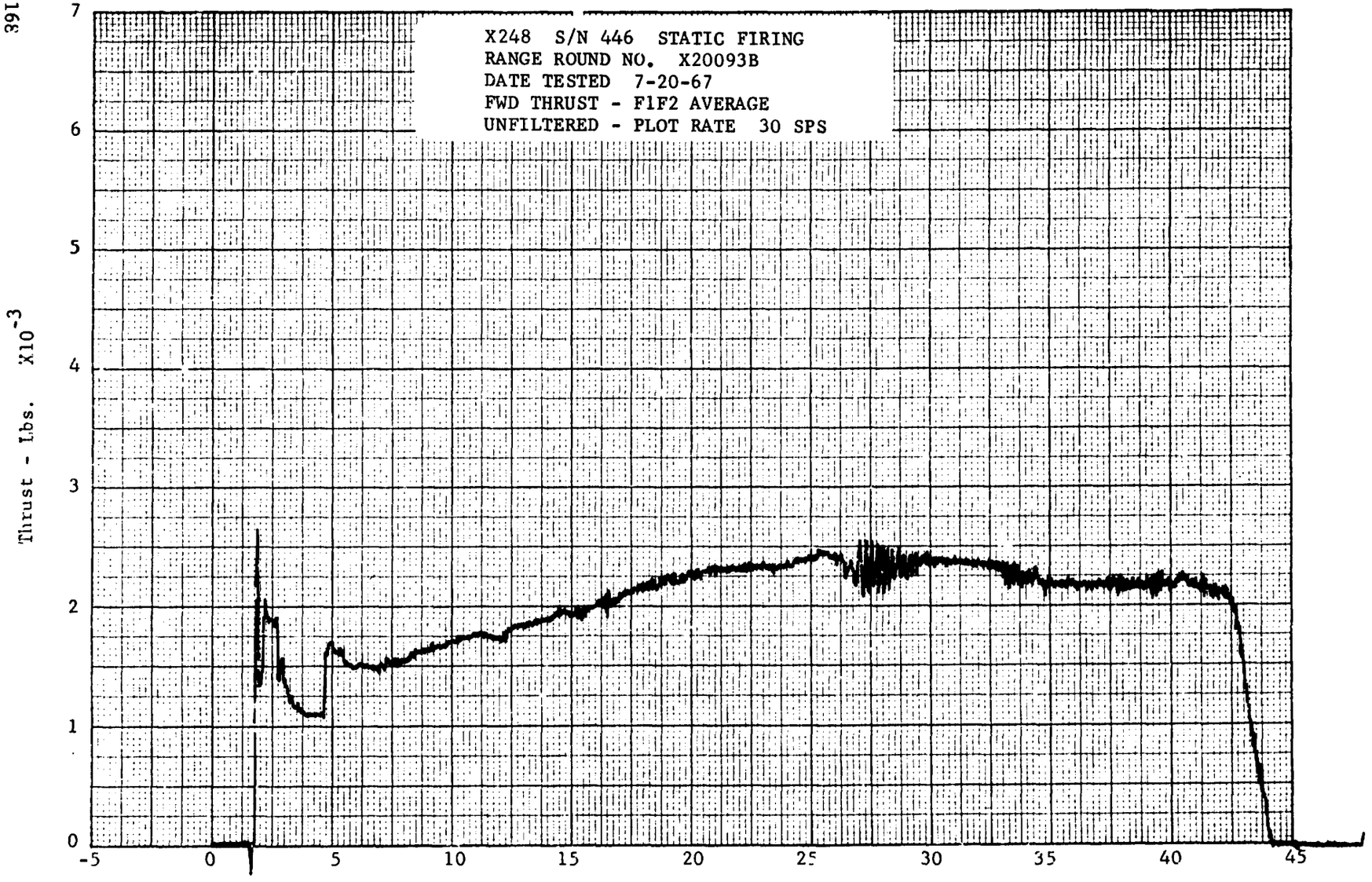
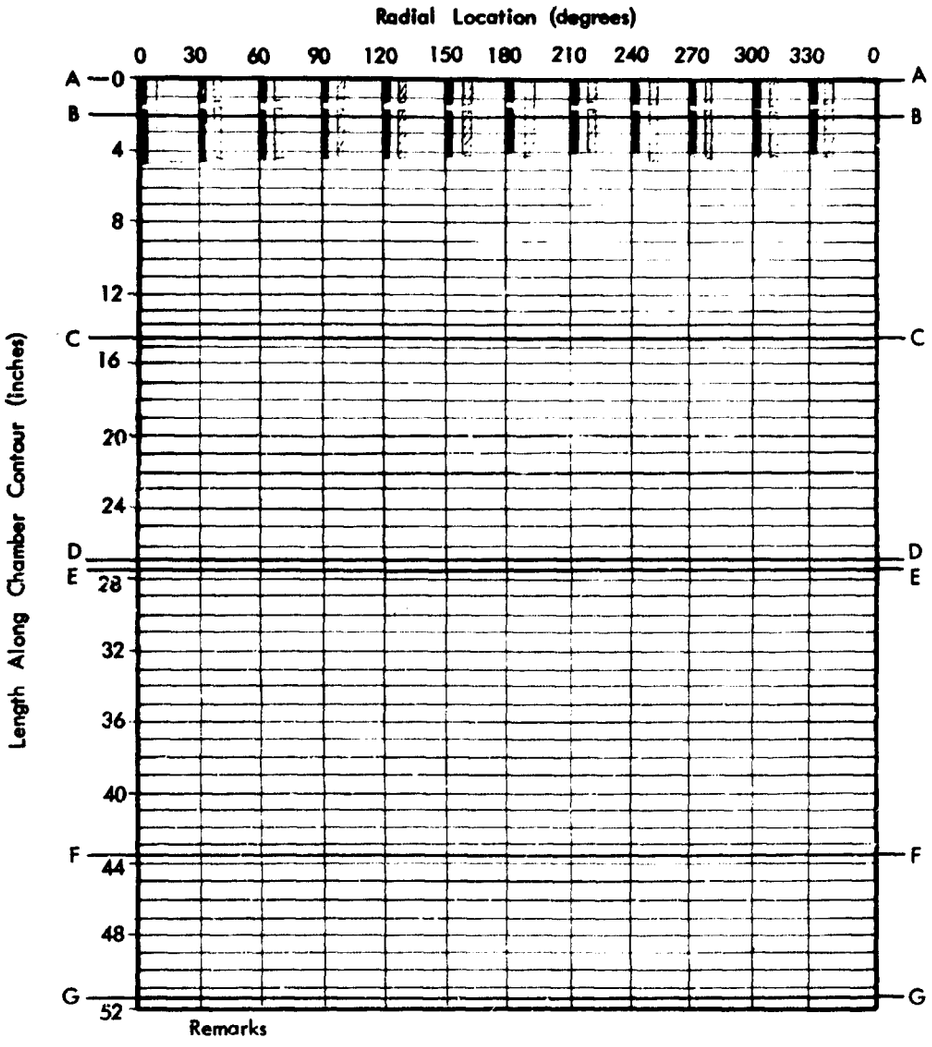
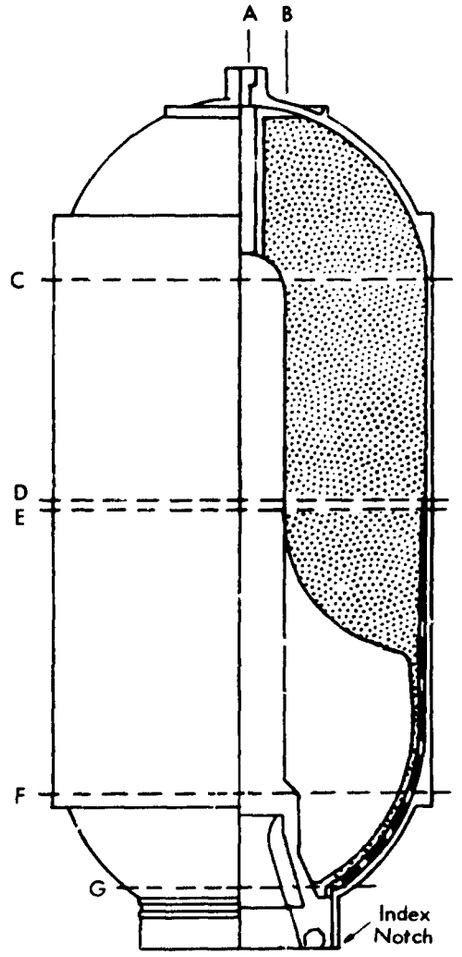


FIGURE 128

X248 RADIOGRAPHIC INSPECTION

Motor No.	MPP-409
Date Inspected	----





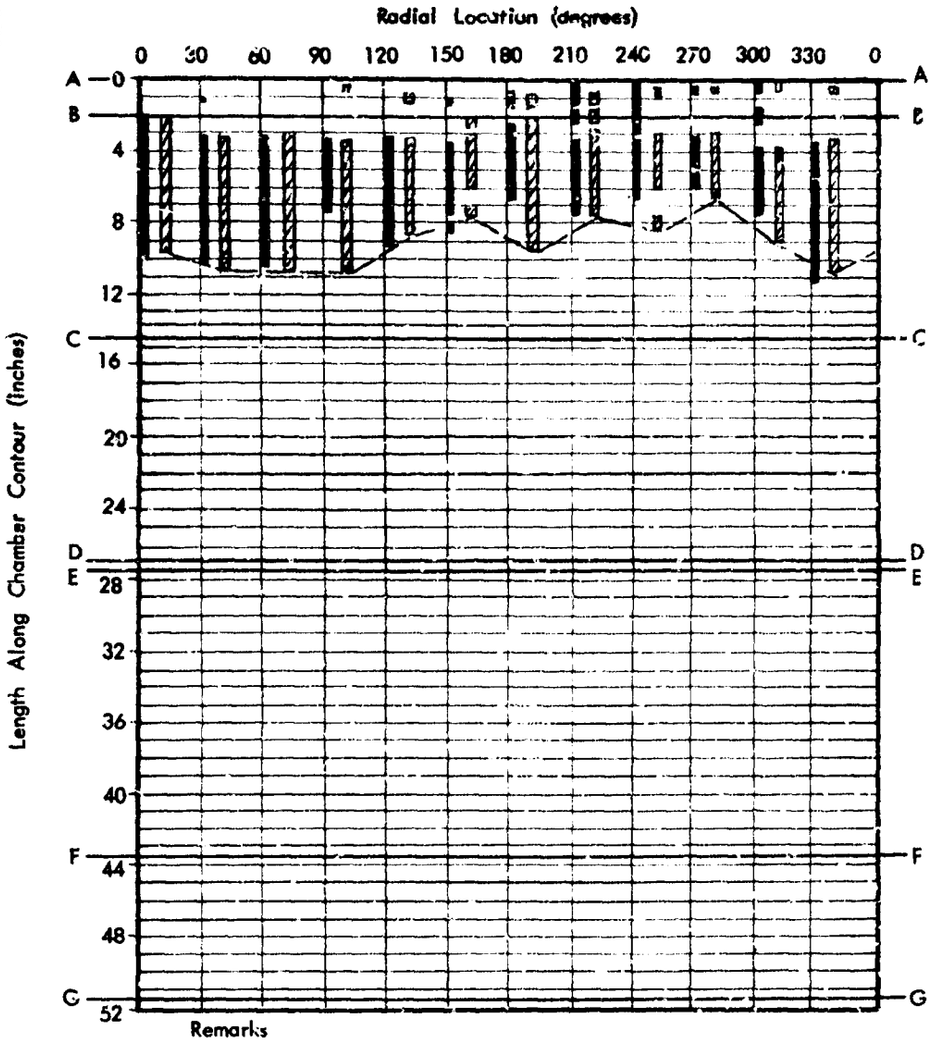
Incoming inspection 10/24/66

Post acceleration inspection 8/12/67

FIGURE 129

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-447
Date Inspecred	As Listed



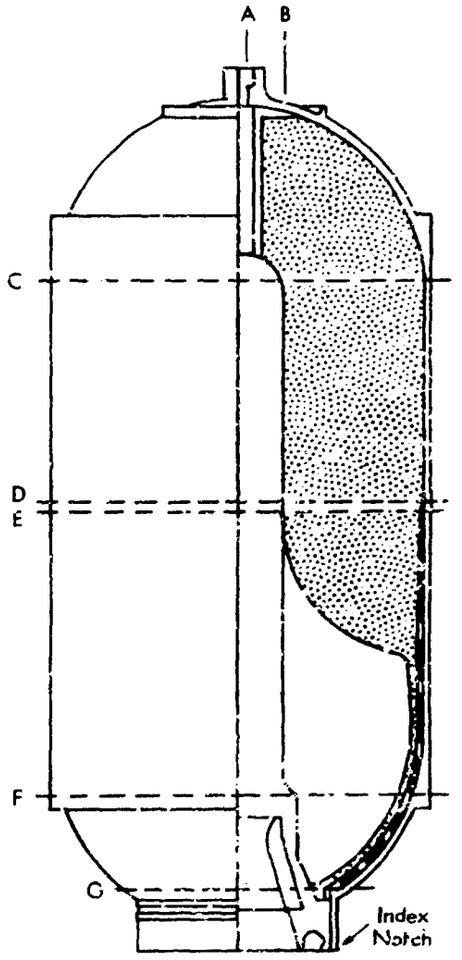


FIGURE 130

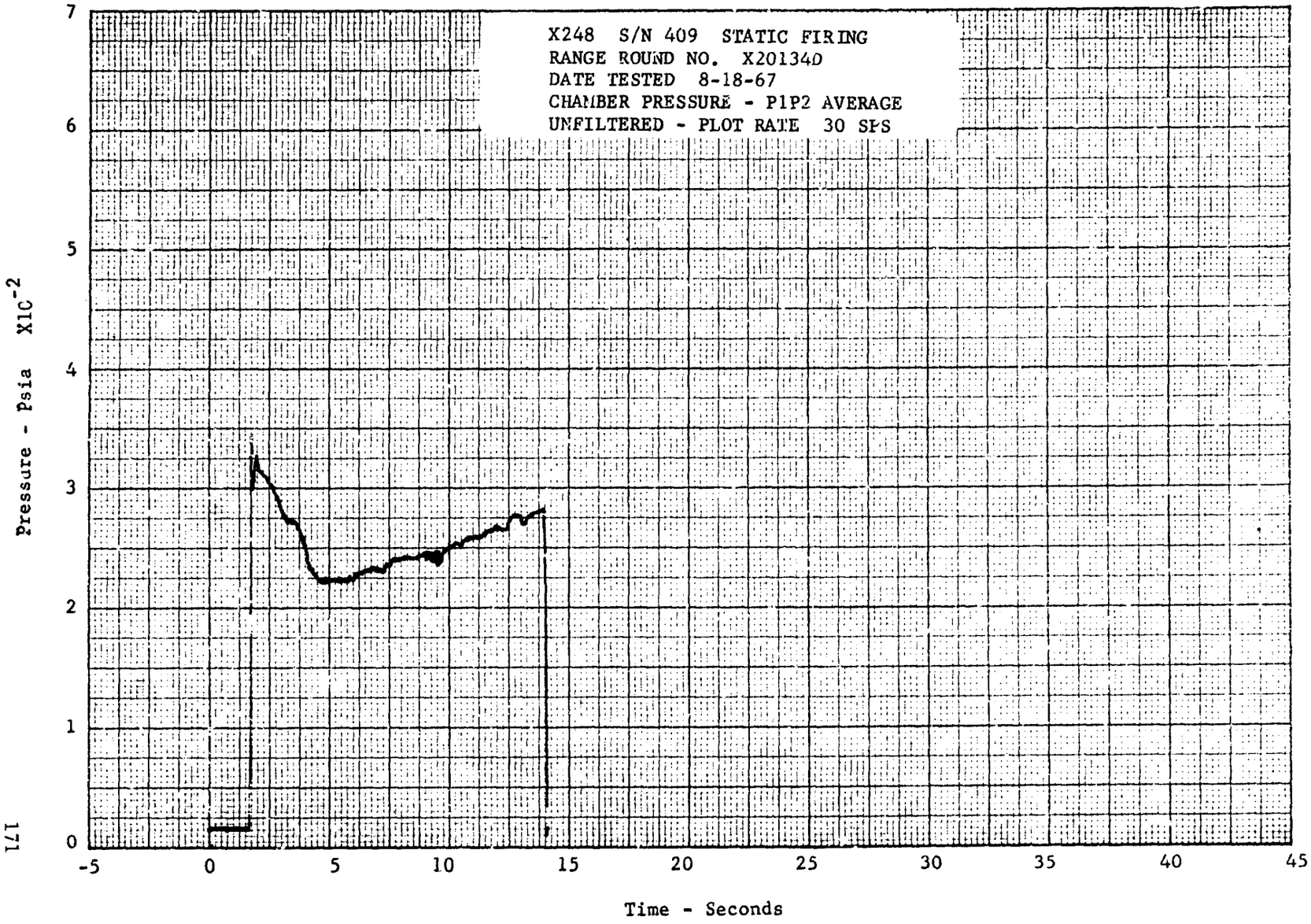


FIGURE 131

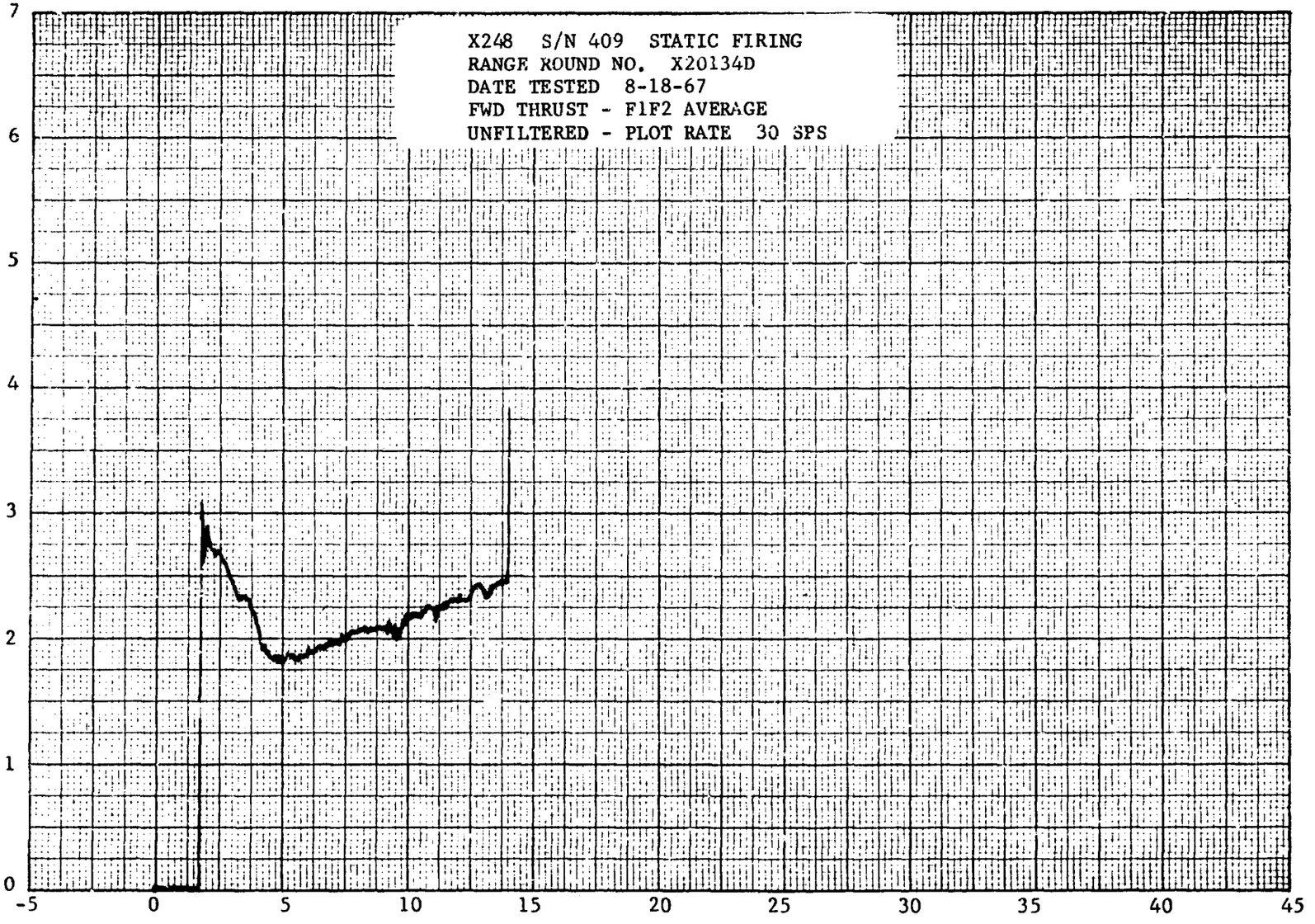


FIGURE 132

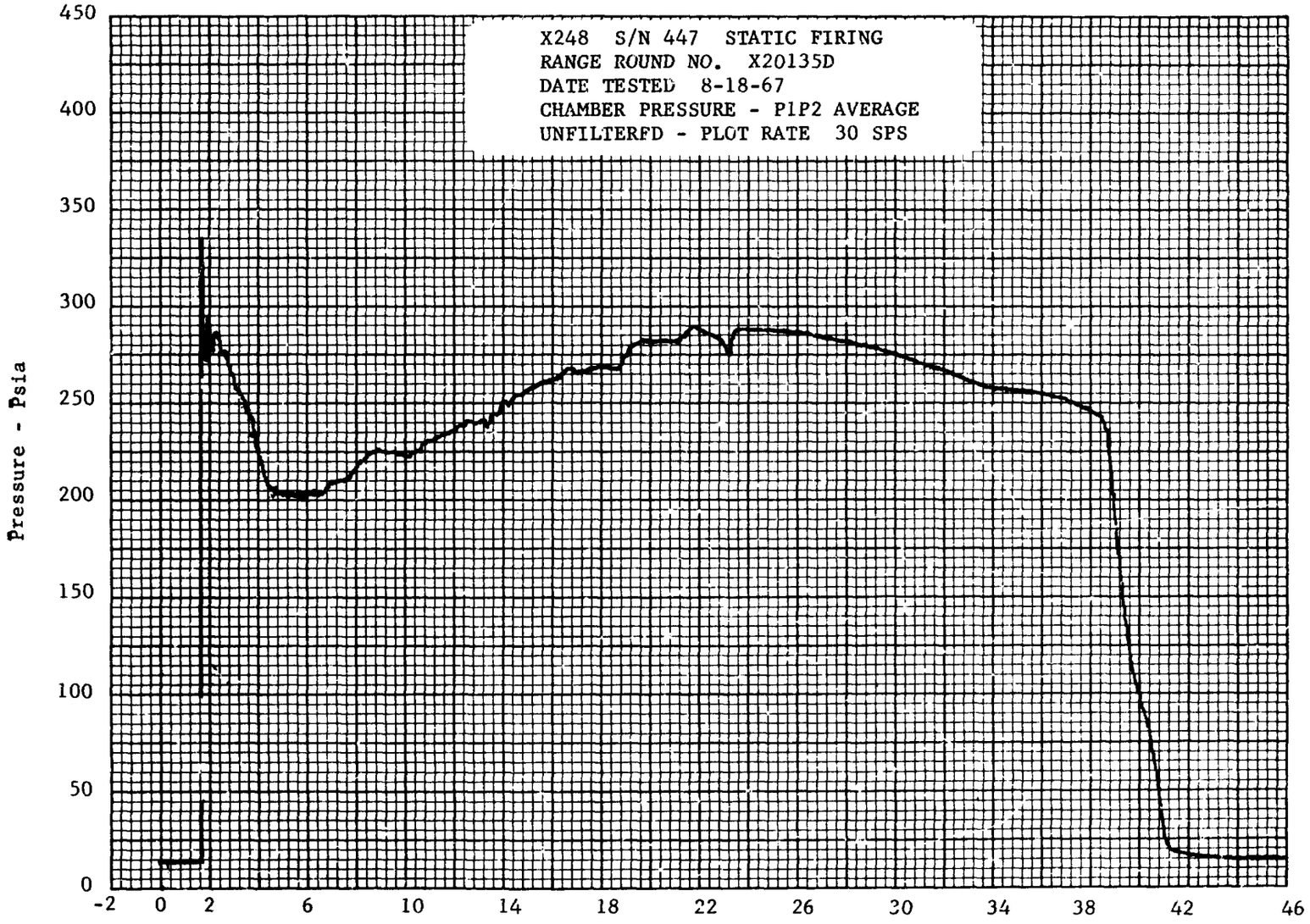


FIGURE 133

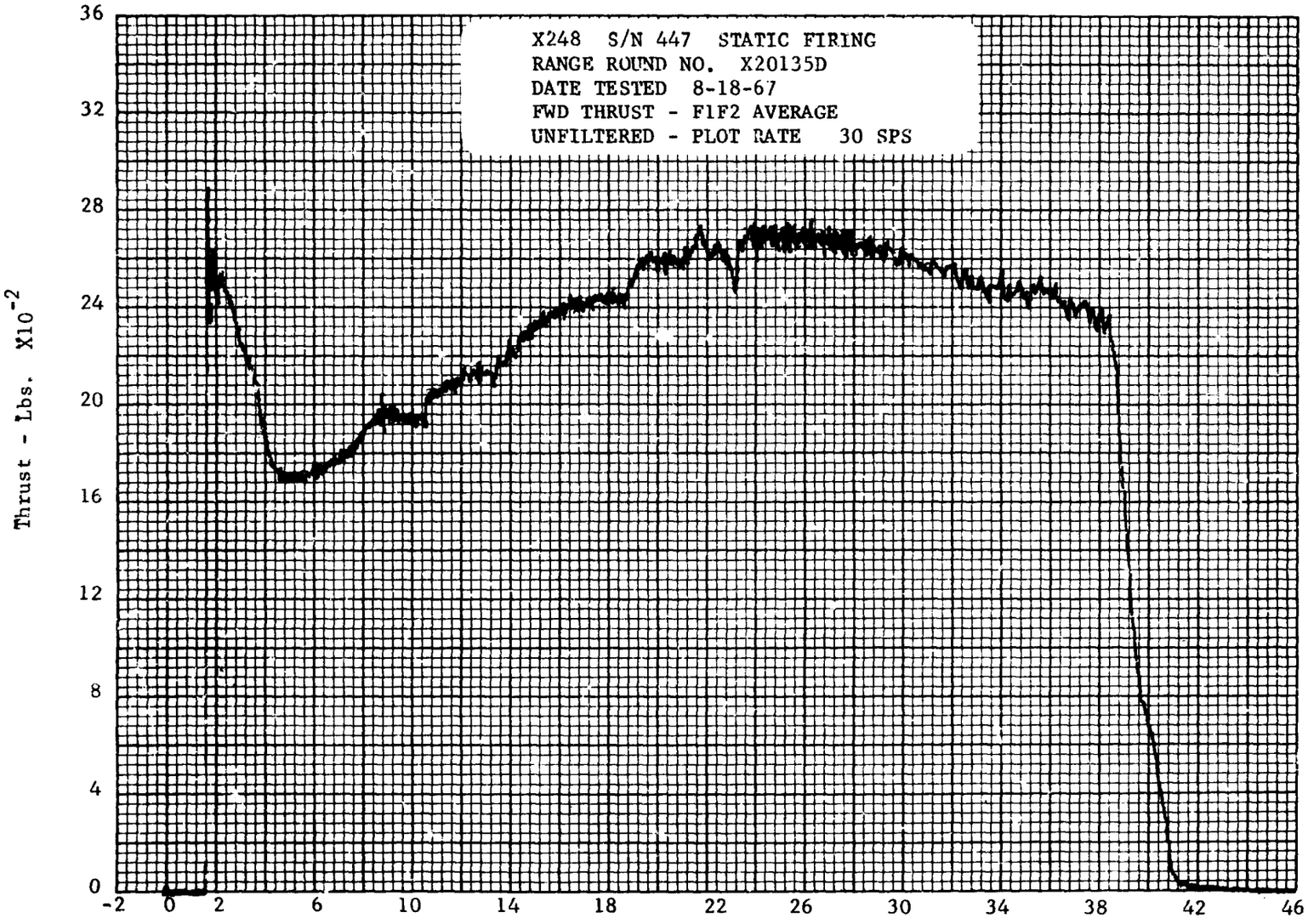
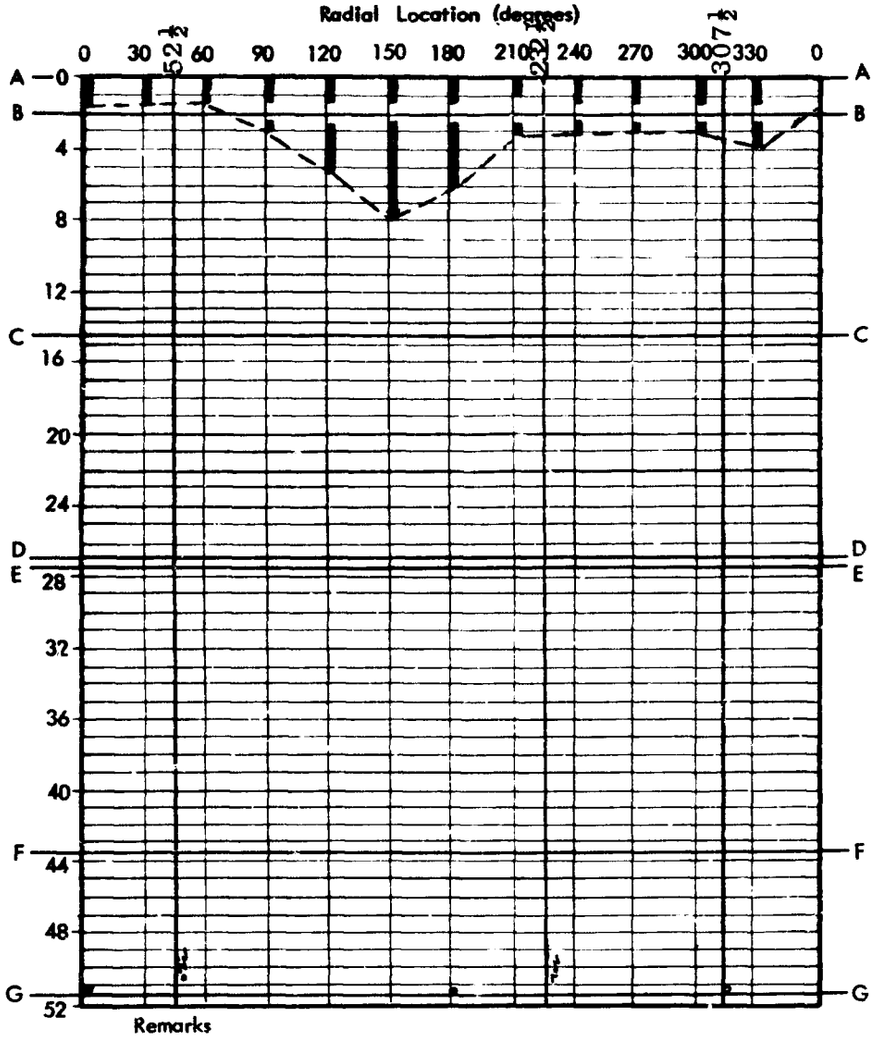
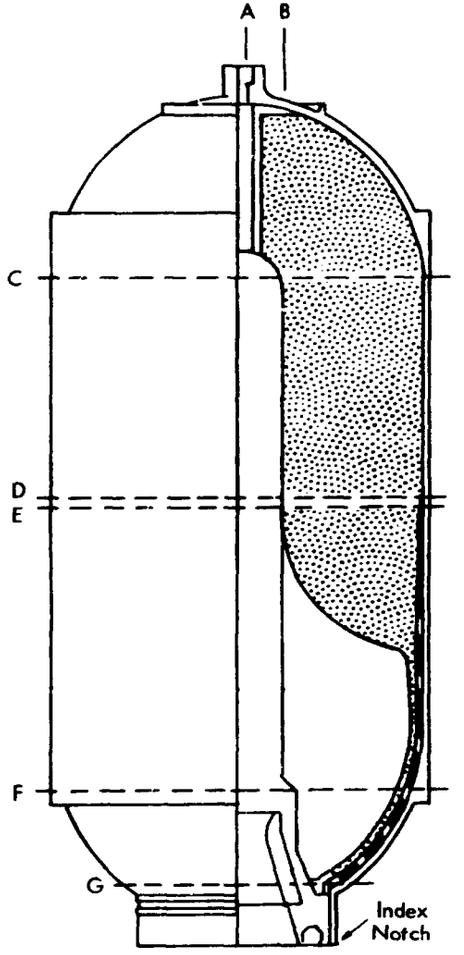


FIGURE 134

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-454
Date Inspected	As listed



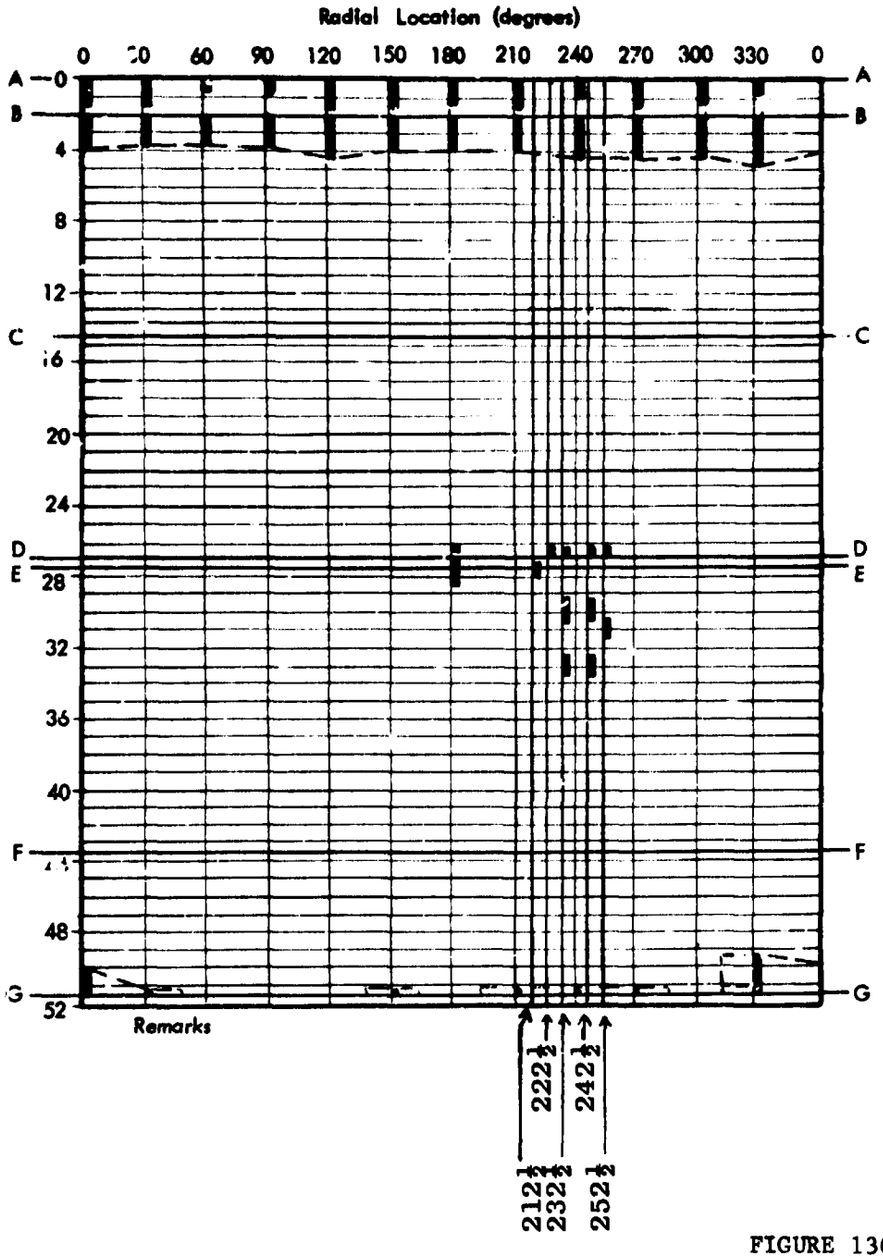


Crack
Void
Separation

FIGURE 135

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-425
Date Inspected	As noted



10/19/66

3/5/68
3/14/68

10/19/66
2/13/68

330° Potted
As of 3/5/68

0° Potted
as of 3/14/68

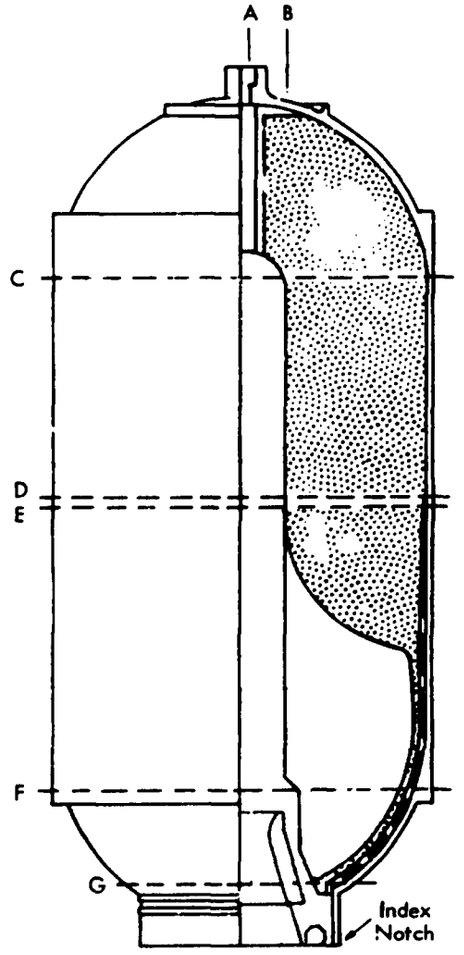
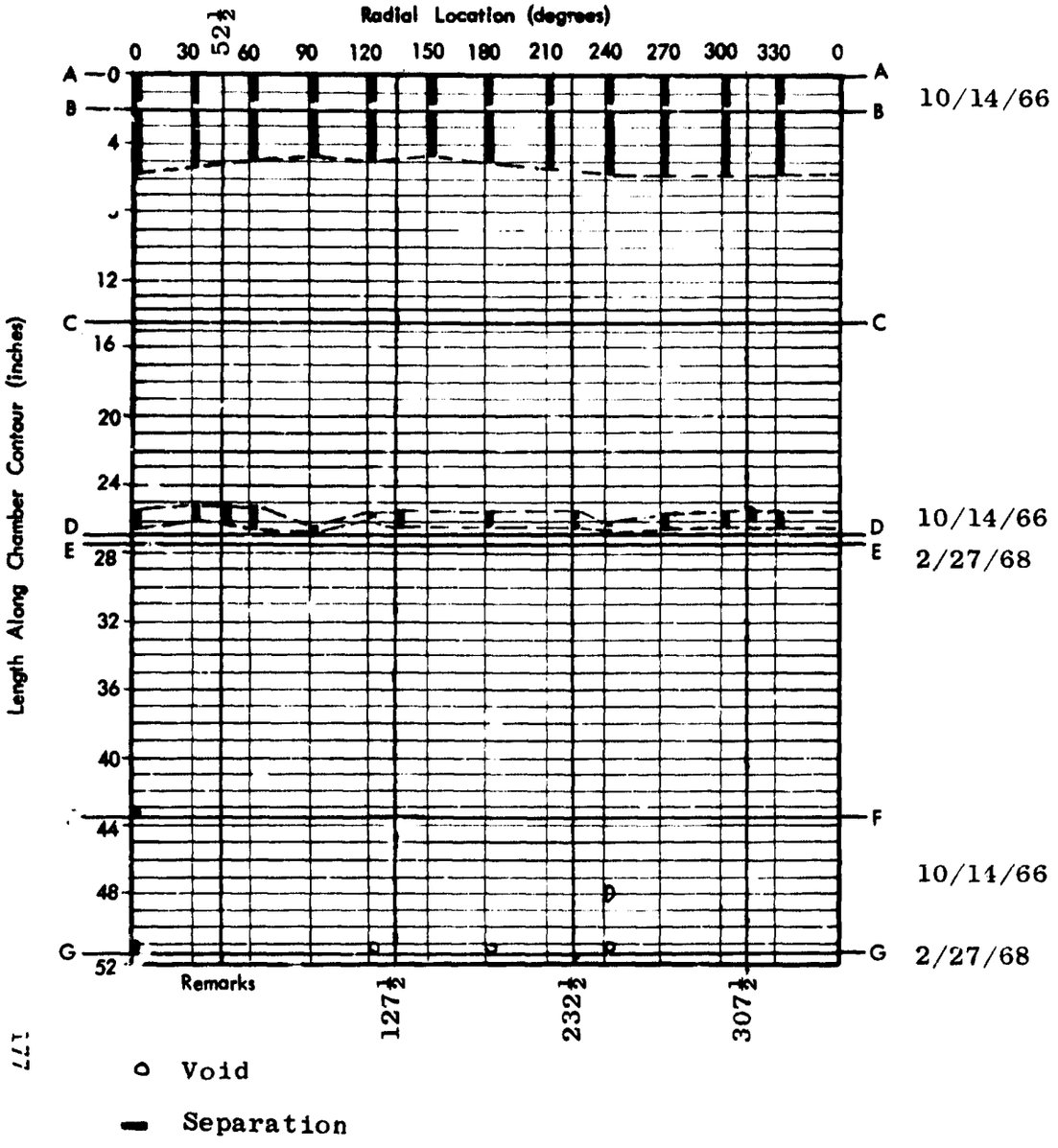


FIGURE 136

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-453
Date Inspected	As noted



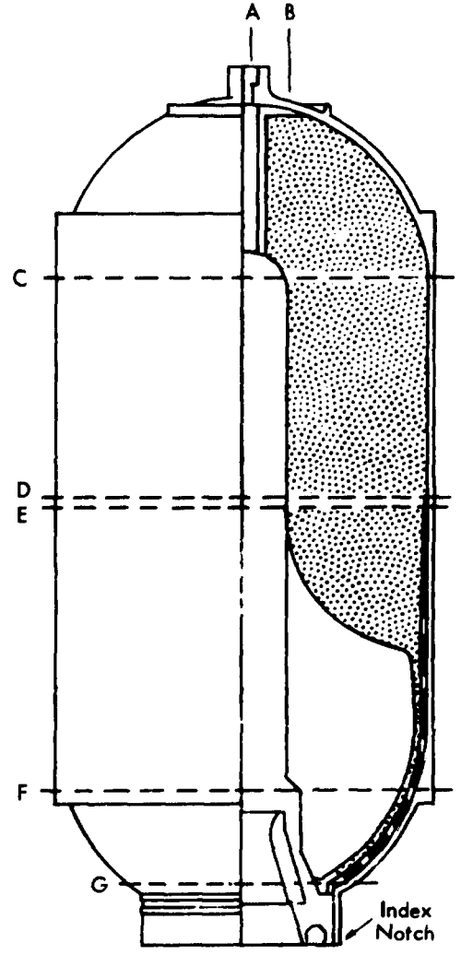


FIGURE 137

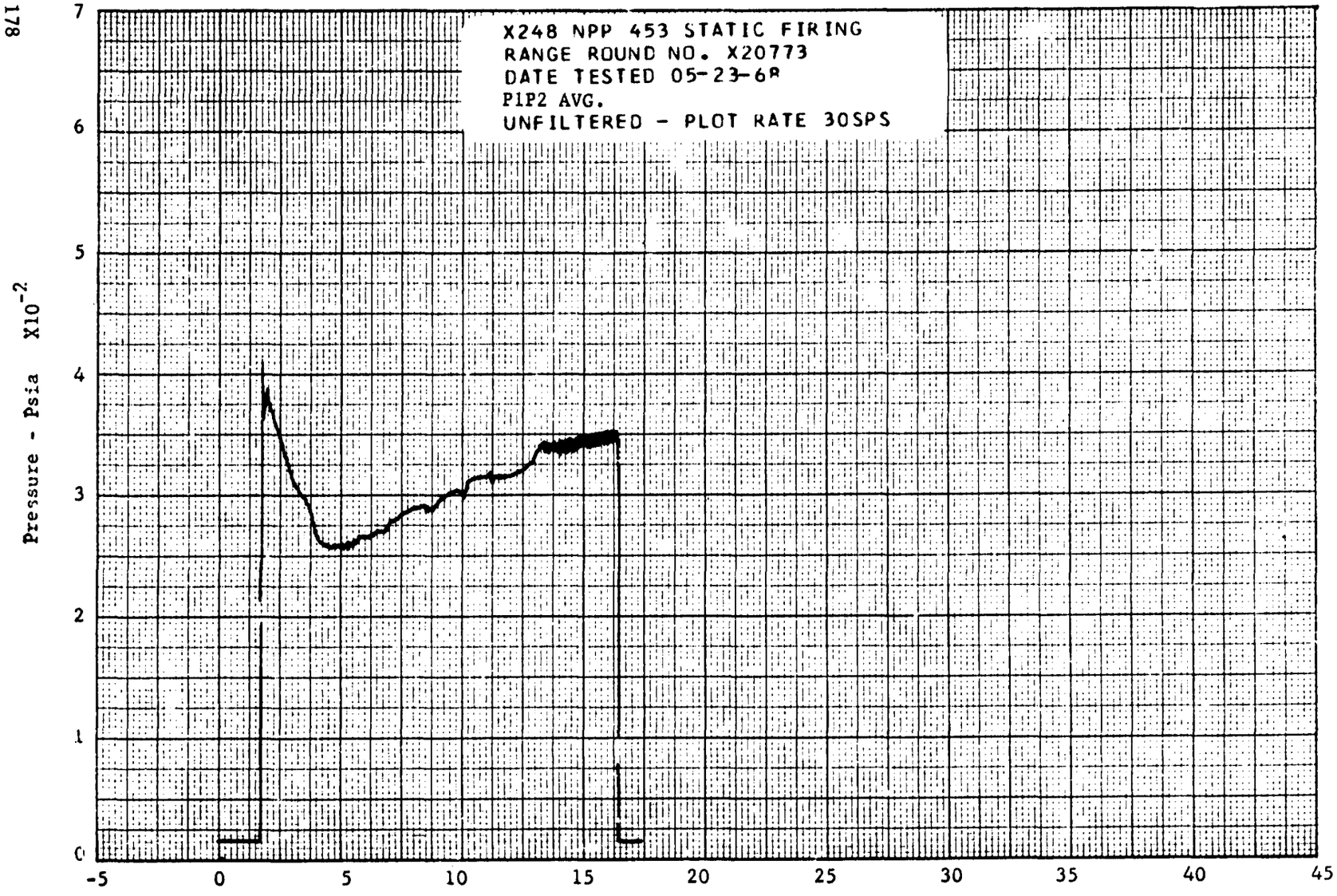


FIGURE 128

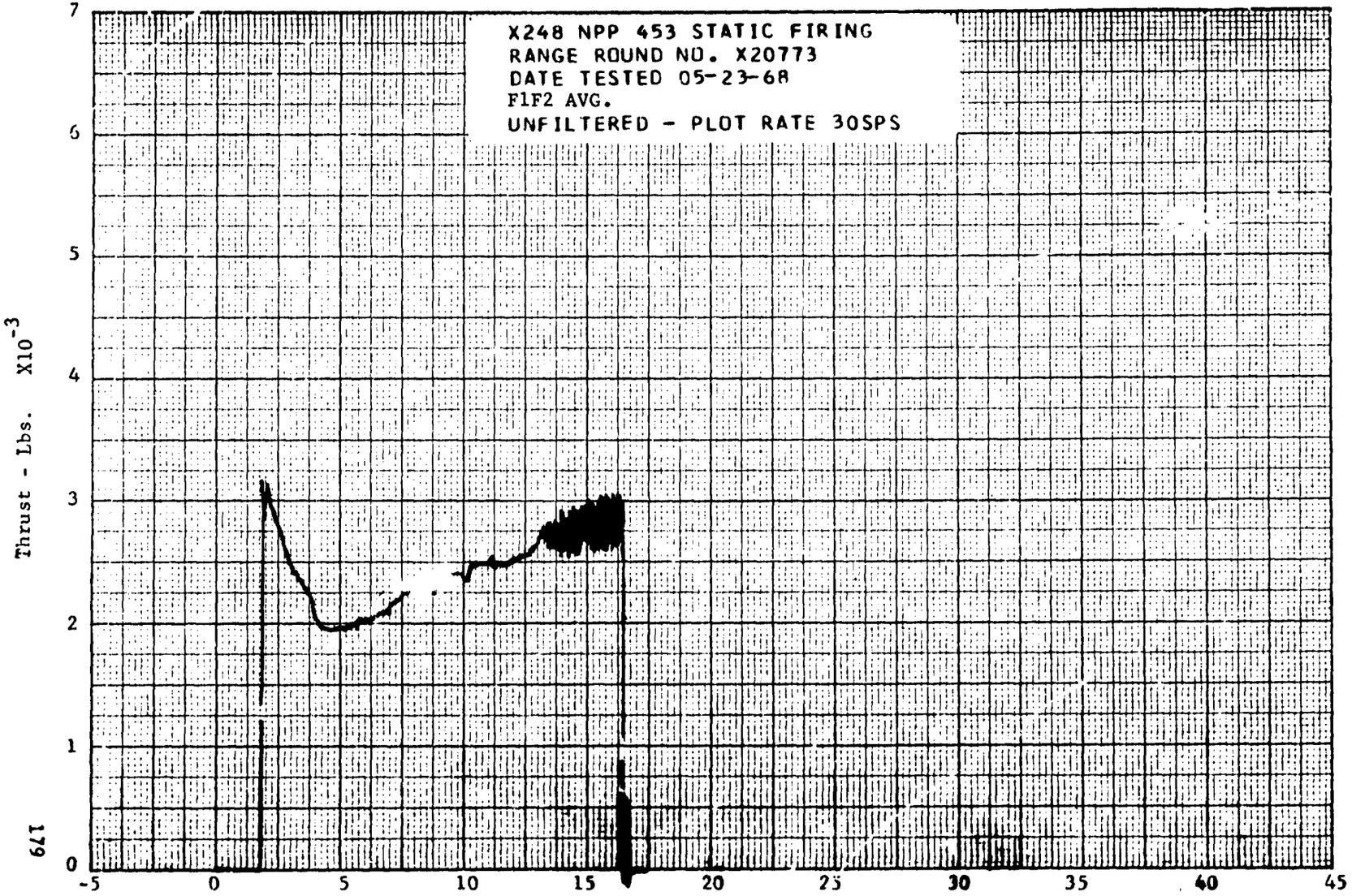
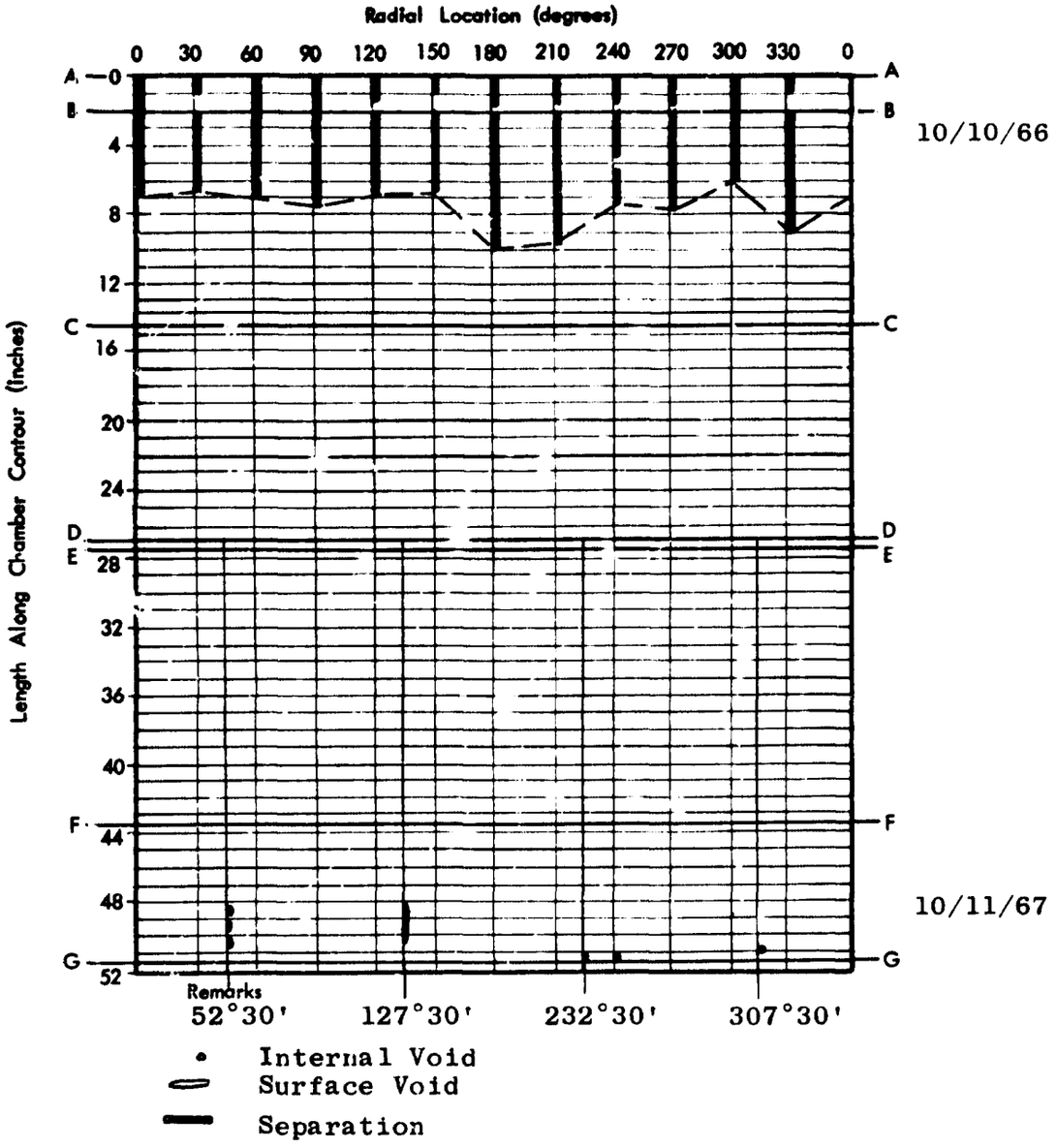


FIGURE 139

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-257
Date Inspected	As Noted



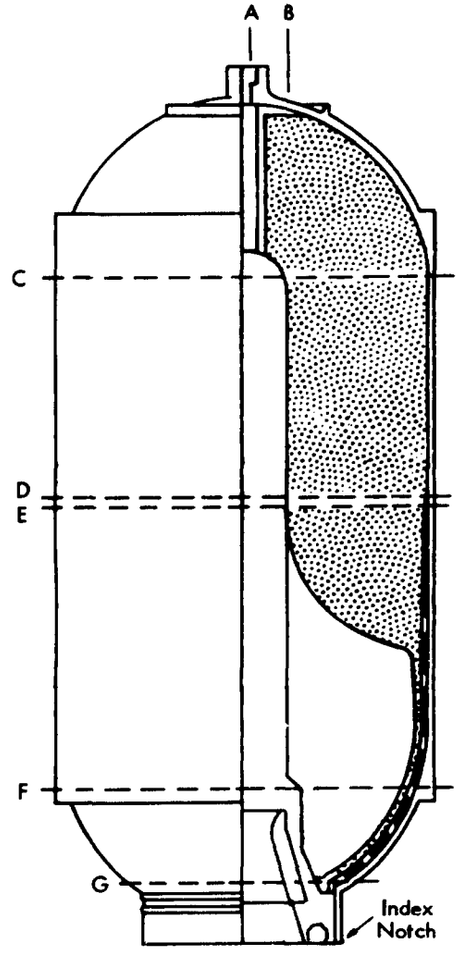
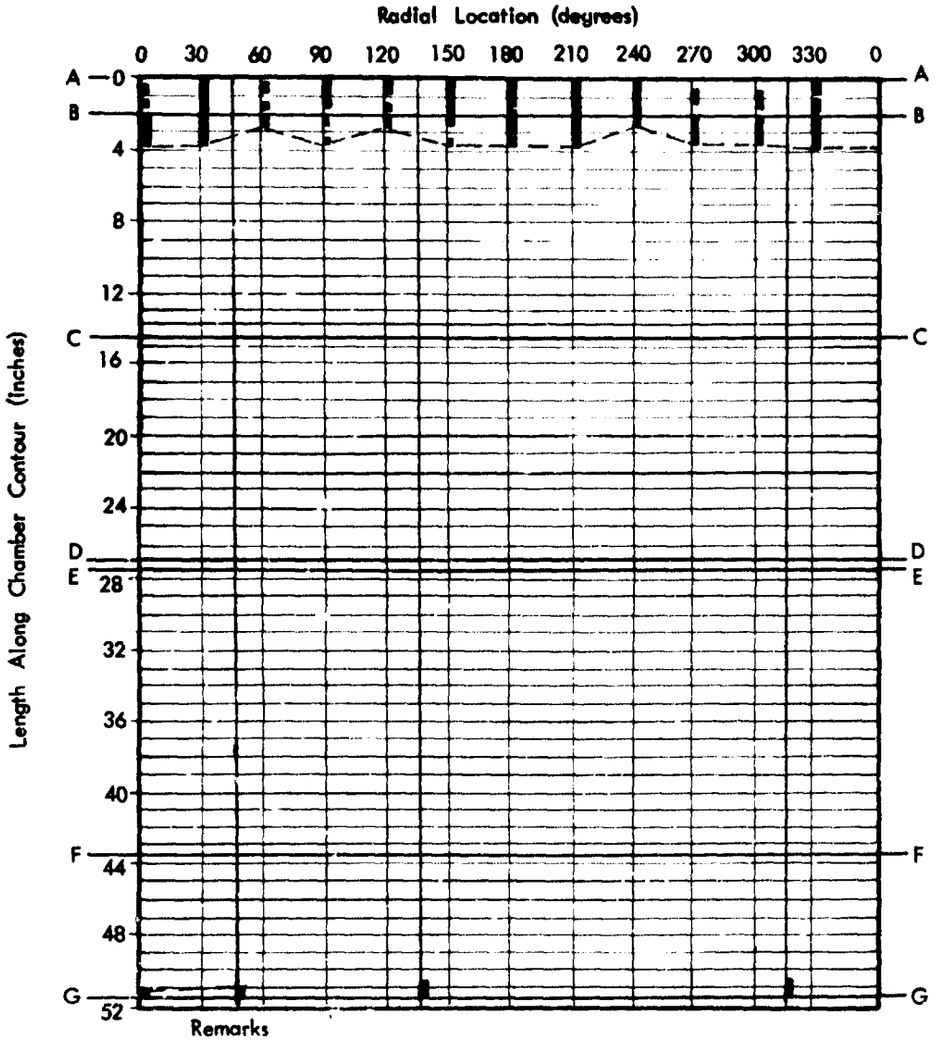


FIGURE 140

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-261
Date Inspected	As Noted



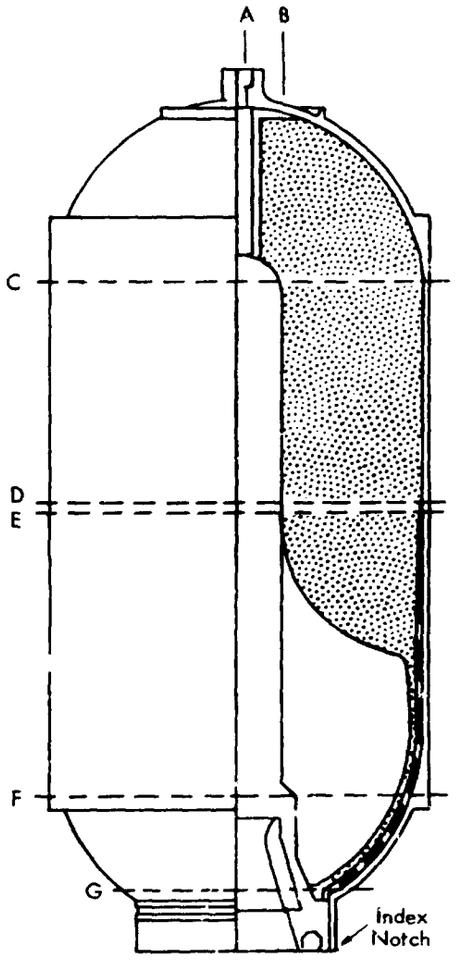


FIGURE 141

X248 RADIOGRAPHIC INSPECTION

Motor No.	NPP-475
Date Inspected	10-21-67

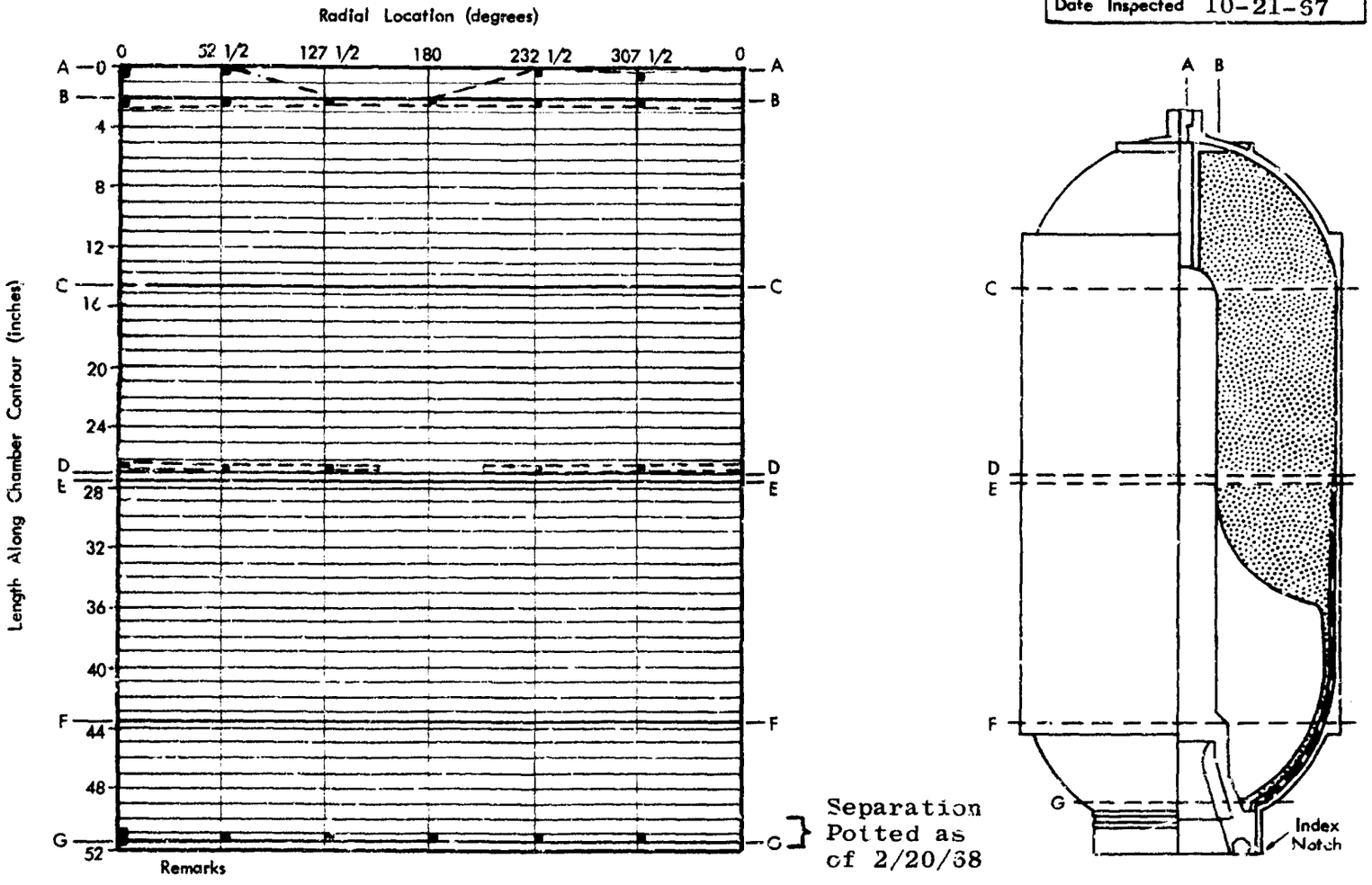


FIGURE 142

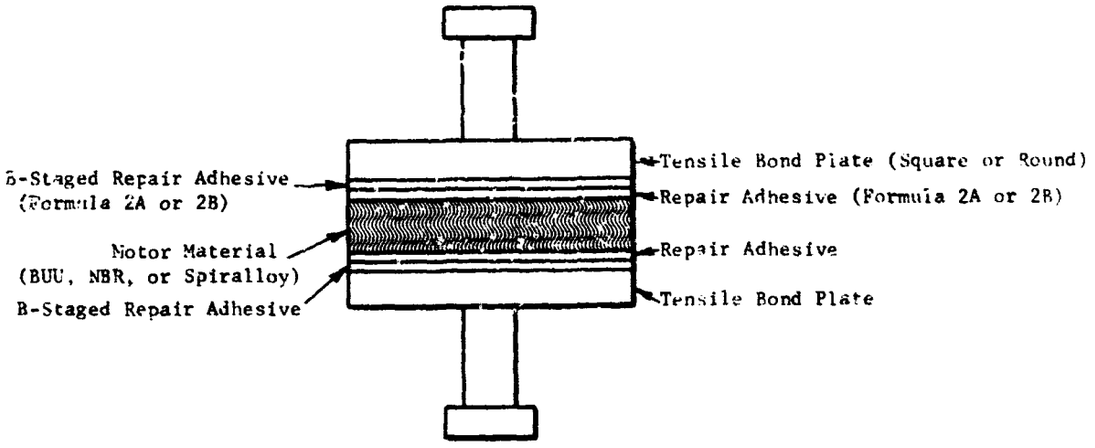


FIGURE 143 - CROSS SECTION OF TENSILE BOND SAMPLES, TO REPAIR ADHESIVE BUU, NBR OR SPIRALLOY

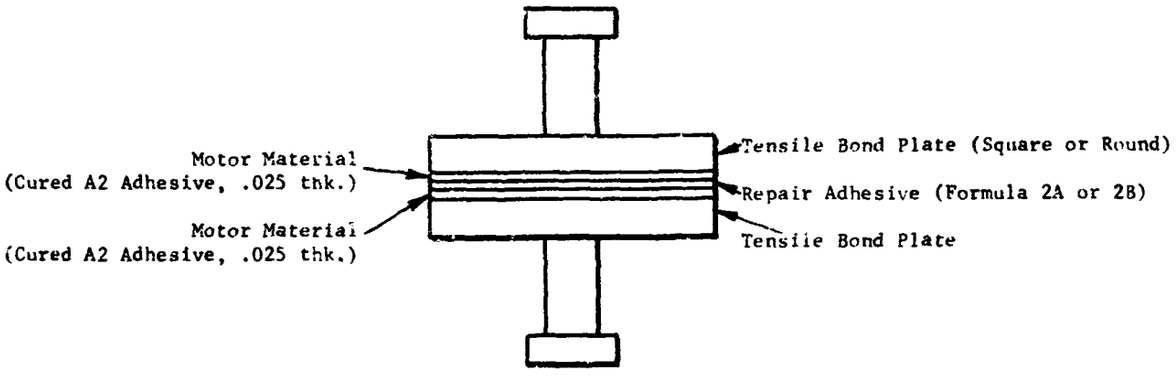


FIGURE 144 - CROSS SECTION OF TENSILE BOND SAMPLES, REPAIR ADHESIVE TO ARMSTRONG A2 ADHESIVE (CURED).

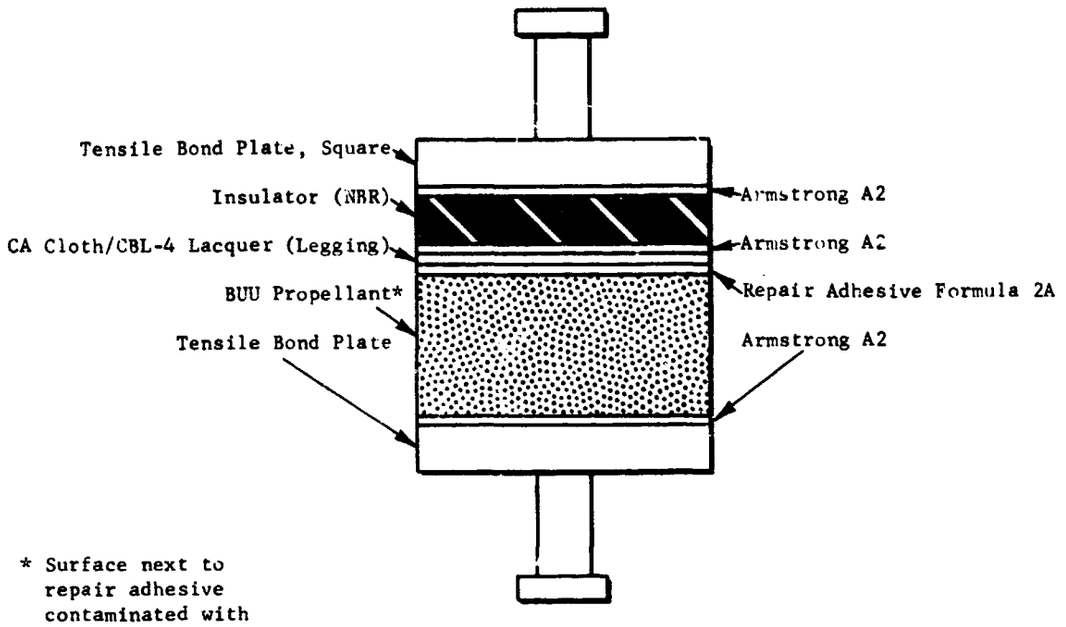


FIGURE 145 - CROSS SECTION TENSILE BOND SAMPLES REPAIR ADHESIVE TO AGED MOTOR CASE BOND INTERFACE